A SURVEY OF PUBLICATIONS ON MECHANICAL WIRE ROPE AND WIRE ROPE SYSTEMS

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INTRODUCTION

A research program dealing with the mechanical properties of composite wire ropes is presently being pursued within the Institute of Ocean Science and Engineering at the Catholic University of America. The goal of these studies is to bring about a more fundamental understanding of the wire ropes based on a scientific investigation of the single wire, the single strand and the complex structural configuration known as the wire rope. Consequently, the research effort, which is both experimental and theoretical, was organized with the aforementioned objective in mind.

The present review was conducted to determine the extent of the literature available in regards to the "Mechanical Response of Stranded Cables". The survey has been organized into three categories, i.e., single wires, single strands and the composite wire rope. The various parameters, such as the mechanical response, the fatigue behavior, corrosion, corrosion protection, shock and impact and others have been considered under each of these major categories.

The review has been organized to enable the maximum utilization of the references presented. Most of the publications are listed with a short comment. An overall discussion of the research material has been given in addition to a complete index. The discussion has been presented in a manner analogous to the overall philosophy behind the research program at the Catholic University.

In a review such as this, omissions are inevitable. It is hoped that they are not major omissions. The authors would appreciate being informed of any material that has not been included but which should have been.

SOURCES

Several compendiums of publications on wire and wire rope were consulted to obtain pertinent information for this literature search:

The British Iron and Steel Institute's Bibliographical Series 13 (399) and 13b (400)provided information on publications dating from the late 1800's to 1958.

The bibliography by Naval Applied Science Laboratory (401) gave information as to past Navy experimental work on wire rope.

Publications relating to problems associated with applications of wire ropes aboard ship are given in the bibliography (398) compiled by the Battelle Memorial Institute.

More recent publications were obtained from the Applied Mechanics Reviews articles for the period 1948 to 1970 (March).

Those publications contained in a previous report (199) on the Themis project at Catholic University and relating specifically to the mechanical properties of wires or wire ropes are also included here for completeness.

DISCUSSION OF THE REVIEWED LITERATURE

I. FUNDAMENTAL INVESTIGATIONS ON THE COMPOSITE ROPE ELEMENTS

A. Properties of a Single Wire

1. Mechanical Response to Simple Loadings

Response of a single wire is actually the response of that wire when acting as the most basic element in the wire rope construction. The uncertainties in attempting an analytical determination of the behavior of individual wires of a wire rope are brought to light in a considerable discussion of a publication by Howe (160). The primary importance of this work was to point out that the helical arrangement of the wires in a rope results in smaller stresses than for a solid bar. The inability to confidently analyze the behavior of individual wires, which persists to this day, has thus placed a premium on experimental determination of load ratings by the various manufacturers (282).

Development of a suitable analysis for behavior of wires in rope is probably a prerequisite to the application of usual engineering development techniques to the design of wire rope systems, e.g., to relate fatigue research on single wires to the fatigue performance of the wire rope.

An alternate approach to the determination of the behavior of the individual wires is, of course, the experimental one. Two previously investigated techniques for determining stresses in single wires which may

deserve further consideration are the electromagnetic method (81) and strain gaging of the individual wires (322).

Other publications that relate to the mechanical response of single wires but which are not considered as part of the wire rope include; an analysis for nominal tension of a wire wound round a circular mandrel (296), the experimental determination of the torsional behavior of a wire under reversed loading into the plastic range (220), and behavior of wire under a combination of a tensile and transverse force (89).

2. Fatigue Behavior

Studies of wire fatigue have been extensive (105). Uncertainties are associated with the determination of the stresses in the individual wires in a rope, as discussed in the previous section. Consequently, direct application of fatigue studies on the individual wires to the determination of the fatigue performance of the wire rope are, at best, uncertain. Some qualitative correlation has, however, been shown (77) for the wires and wire ropes.

Experimental studies of wire fatigue have included tension (361), bending (230), and torsion (361). Factors which have been shown to influence the fatigue life of wires (in addition to the applied stress range) are:

(a) Mean Stress - Two investigations were conducted to determine the effect of the mean stress on the limiting range of alternating tensile stress. The first study (309) dealt with the following types of wire: cold-drawn and galvanized, heat treated and galvanized, and high-carbon steel wire electroplated with zinc. The second study (263) dealt with two steel wires of the same composition - one in the drawn, patented condition and one in the tempered state. Results indicated that the alternating stress was practically

independent of mean stress for the first study and completely independent in the second case.

(b) Cold-work (percent reduction in drawing) - Fatigue properties of carbon steel wires have been shown to improve with low rates of drafting (smaller reductions per pass for the same total reduction). The improvement in the fatigue properties due to low drafting rates increases as the carbon content increases. Other work (126) has indicated that larger percent reductions increase the tendency for the effect of a decarburized* surface to obscure the beneficial effect on fatigue strength of an increase in carbon content. In addition to the magnitude of cold work, effects on fatigue properties have been shown (265) as a result of variation in the rate of running through the dies.

(c) Heat Treatment - Low temperature heat treatment (tempering), which is performed on the severely cold-drawn wire, has been shown (127) to give a general increase in fatigue strength. Optimum tempering temperatures are in the range of 200-250°C, independent of carbon content or degree of cold work (percent reduction in drawing).

(d) Carbon Content - In general the endurance (fatigue) limit of steel wires increases with an increase in carbon content (77, 126, 135); however, it has also been shown (77, 126, 135) that the endurance (fatigue) ratio, defined as the ratio of the endurance limit to the ultimate tensile strength of the wire, actually decreases with increasing carbon content. Since increasing carbon content is also associated with an increase in tensile strength, the latter observation indicates a lower capacity for cyclic

* remov [illegible] hard martensite by a processing heat treatment

loading for a wire rope composed of wires of high tensile strength, as compared, for example, to a rope composed of wires of lower tensile strength but which is capable of supporting the same ultimate load.

(e) Surface Coatings (galvanizing) - At least one comprehensive study (365) indicates that galvanizing tends to lower the fatigue life of steel wire. The effect was found to be greatest for hot-dip galvanized wires (reduction in fatigue limit of from 15 to 28 percent), as opposed to that for electrolytically coated wires. The hot-dipped wires were observed to develop closely spaced hair-line cracks perpendicular to the surface; whereas no such cracks were observed to occur in the electrolytically coated wires. The latter observation would tend to suggest that the inferior fatigue properties of the hot-dipped galvanized wires may result from notch effects due to these hair-line cracks.

(f) Others - Limited information was found relating to several other factors affecting the lives of wires in fatigue, among these: the effect of periods of rest (67), the effect of decarburization of the surface of the wire (105,126,127), the effect of corrosive atmosphere (263), and the effect of surface finish (131,309).

3. Corrosion Effects

Studies on the effects of corrosion on the behavior of wires can be broken down into three main categories: the first deals with the reduction in the cross sectional area of the wire due to either general wastage (37) or else due to severe localized pitting (134), the second is the effect of corrosive environments in combination with cyclic loadings of the wire (corrosion fatigue) (263), lastly, and lately receiving considerable attention, is the effect of critically localized corrosion or stress corrosion cracking

(37). Localized corrosion, in the above sense, means that the area of concern is restricted to a small process near the tip of either a pre-existing crack or else a crack which has initiated and subsequently propagated as a result of the cyclic loadings.

Other publications relating to corrosion of wires deal with corrosion resistance of stranded steel wire in sea water (277) and the effect of sea water on wires and wire rope (255).

4. Cathodic and Other Environmental Protection

Protection of wires against corrosion may be either of two basic types, i.e., cathodic protection or else protection with coatings (individual wires or jacketing of the entire wire rope), where these coatings may also serve to provide mechanical protection (abrasion, fish attack, etc.).

For corrosion protection, at least two comprehensive corrosion analyses of deep sea mooring systems, indicate a decided superiority for cathodic protection over protective coating systems. Specifically, in (203) it was shown that in cases without cathodic protection, even wires jacketed with neoprene were severely corroded (crevice corrosion in the 304 stainless steel); conversely in (139) it was found that for areas where a bituminous coating substance was damaged, the cathodic protection prevented severe corrosion.

It should be noted here that galvanization of the individual wires is also a type of cathodic protection. However, in light of the observed deleterious effects of galvanizing (particularly the hot-dip process), pointed out in a previous section on fatigue of wires, the use of galvanized wire may not be the most efficacious approach to combating the corrosion problem, par-

ticularly if fatigue loadings are to be appreciable.

B. Properties of a Single Strand

Based on the relative number of publications found in the course of this survey, less attention has evidently been paid to the strands of wire rope as separate entities than to either the individual wires or the complete cable. Those publications which were found include: an attempt (234) to predict the load taken by each strand of a steel-cored, aluminum conductor cable; and development (250) of an equation for bending moment of a pretensioned rope at an anchorage, from which the stresses in the strands may be predicted.

Contact stress conditions between layers of strands within a cable have been determined (86) experimentally using photoelasticity.

Investigations were performed for single-lay cables, such as (249), where the effect of contact pressure on stiffness of cables under tension and torsion was obtained using Kirchoof's thin rod theory. Such studies may point the way toward future study of the helically arranged (224) strands - of similar nominal composition - of wire ropes.

II. APPLIED INVESTIGATIONS ON THE COMPOSITE ROPE SYSTEM

A. Constitutive Relations

1. Mechanical Response under Various Loading Conditions

Sources of loadings on wire ropes are manifold and are discussed extensively in the literature; e.g., hydrodynamic loadings (10, 11, 69, 196, 257), loads due to mooring (20), hoisting loads (dynamic loads), (194), and

loadings in cables of suspended cable transport devices (64).

The result of the imposition of the external loads, i.e., the internal load resultants on the wire rope cross section may be either; tension (4, 171, 192, 197, 225, 236, 271, 320, 352); bending (3, 100, 297); torsion (102, 103, 125, 167, 201, 348); or combinations of the above such as combined tension and torsion (22, 222, 249), or combined tension and bending (250).

Publications relating to the response of wire ropes to various loadings include those for: deflection of horizontal cables due to the application of concentrated loads (such as suspension bridge cables and cables used in suspended cable transport devices) (109, 110, 140, 176, 219, 242, 243), elongation and reduction of the diameter of cables due to axial tension (397), twisting of cables of unbalanced construction due to the application of hanging loads which are free to rotate (103, 222, 224), bending of wire rope in flying foxes (used in aircraft arresting gear) (281), and bending strain in conductor cables (259, 297).

2. Development of Analytical Models.

(a) Models for Stress in Wire Rope - Two basic approaches have been used in attempts to develop analyses for stresses in wire rope. The first is the equivalent modulus (stiffness) concept (160, 167), wherein the modulus of the rope as a whole is determined experimentally and used in formulas which are developed based on the usual elastic analyses relating stress to load (tension) or curvature (bending about a sheave). Recently at least one attempt (13) has been made to analyze the wire rope as an assemblage of coiled springs (245) and to use the theory of spiral spings to determine the axial elongation of the spirally would cable.

(b) Models for other Wire Rope Characteristics - Other analytical efforts relating to the response of wire rope include: determination of tensile (249) and torsional (102, 103, 125, 249) stiffness of cables and elongation due to untwisting of ropes under longitudinal stress (291), deformation of steel wire ropes under an axial load and a twisting moment (129), nonsymmetric extension and the "spin" phenomenon in steel cables (13), behavior of suspended cables under a horizontal distribution of loads, uniformly distributed or concentrated (conductors, suspension bridge cables, antenna guy cables, tramways, etc.) (164, 229, 236), tension in ropes (192) or wires (216, 296) wound about a cylinder, dynamic loads due to hoisting (260, 289, 290, 292, 293, 294, 295 - primarily work done in the Soviet Union), and behavior of a cable running over a pulley (62).

(c) Models for Wire Rope Systems - Included in this category are; a computerized solution for structural analysis of moorings with several fixed points (141), and analyses for wire rope networks including structural nets (12) and prestressed cable networks (such as used in roof construction).

3. Effect of Core

Wire rope cores may be of the fiber type (either manila, sisal or polypropylene) or else of the independent wire rope type. Conclusions of Reference 397 on the effect of the type of core on the response of wire ropes in tension were: (a) that cables with fiber cores have the largest dimensional changes (as characterized by the ratio of the negative of the transverse strain to the longitudinal strain), and (b) that the type of core affects the modulus of the wire rope (lower modulus for fiber core). The type of core was not, however, observed to affect the total input energy required for the first cable failure.

In a survey (82) of problems related to the Navy's use of wire rope, the question was raised as to the effect of the type of wire rope core on the endurance (fatigue capability) of wire rope used in replenishment operations.

A mathematical model of wire-core interaction (stress concentration) at a clamp or apparatus housing for an armored submarine cable is presented in Reference 214.

4. Effect of Lubricants

The importance of proper lubrication on the life of wire rope has been repeately emphasized (1-9, 274). Specific beneficial effects noted are (206): preservation of natural fiber cores; retardation of corrosion; reduction of friction between wires; delaying the onset of fatigue. In certain instances, Navy lubrication practices have been described (82) as either improper (application of a thick coating of grease rather than a thin slurry which can penetrate the fibers) or else as neglected entirely.

B. Failure Criteria under Varying Conditions

Results of a survey by the U.S. Naval Oceanographic Office (48) to determine the causes of failures (parting or breakage) of wire rope indicate the following order of importance for the various causes of failure:

Rank	Reason for Failure	% Cases Reported
1	Unsuitable construction	28
2	Fatigue	20
3	Corrosion	14
4	Shock	12
5	Erosion, Scuffing and Local Wear	8

6	Insufficient Strength	4
7	Improper Handling	4
8	Improper Lubrication	4
9	Variable Rope Quality	2
10	Other (Electrical)	4
		100

A discussion follows on available literature dealing with failure criteria for the three most important causes for failure given above (Ranks 2, 3 and 4) which relate to the mechanical properties of wire rope, i.e., fatigue, corrosion, and shock. Also work related to fatigue will be included in publications related to 5 above, i.e., erosion, scuffing and local wear.

1. Fatigue

Fatigue damage to wire ropes, i.e., that due to repetitive applications of load, results from (44)*: (a) repeated axial loadings, (b) strumming, (c) dancing, (d) shock loads and (e) bending over sheaves (bending stresses, radial compressive forces, abrasion and fretting).

The definition of fatigue failure of wire rope is arbitrary but is generally stated in terms of the number of broken wires per linear measurement of rope (66). Depending on economic or safety considerations, failure could conceivably be considered as occurring between the first wire failure and complete fracture. With progressive failure of wires the remaining tensile strength of wire rope is decreased (73).

* Problems in oceanographic applications have been shown to be analagous to problems in the power industry.

Presently, it is considered (280) unfeasible to reliably predict even the most elementary type of fatigue failure, i.e., the first occurence of a broken wire.

It is generally held, however, (91, 280) that the location of the most serious fatigue damage occuring in wire rope systems is at those places where the wire rope is bent over sheaves. Here, in addition to the axial stresses, severe bending stresses (depending upon the severity of the bend) are superimposed. At least one investigation (330) indicates that, in fact, the largest contribution to the stresses in wire rope is from the Hertz contact stresses at points of contact between individual wires, and that the usual mode of failure is fretting-fatigue at the contact points.

The sole theoretical method available for estimating the fatigue life of wire rope is the dimensional analysis performed by Drucker and Tachau (91). In that work a dimensionless bearing-pressure parameter, B, relating tension in the wire rope, tensile strength of the material, diameter of the rope, and diameter of the sheave was proposed (note that this parameter can conceivably account for tensile, bending and contact stress) The usefulness of the parameter derived was demonstrated when lives for several ropes of two different constructions, 6 X 9 and 6 X 37, fell on a smooth curve (life vs. B) with scatter less than that which would be expected using the usual test parameters.

2. Corrosion

Based on the literature which is available, the emphasis of the research conducted to date has been concerned with general wastage due to corrosion and to comparative studies (391) of various wire rope materials

and protection systems for their resistance to general wastage.

Except for investigations which have shown the region of failure of a wire rope to be that at which cathodic protection was inadequate (139), no criterion was found which would relate the severity (rate) or extent of corrosion (percent of cross sectional area) to the time to failure or failure load respectively.

Since, in certain cases of corrosion, the reduction in cross sectional area may be relatively localized (with respect to the cable length), e.g., in 304 stainless wire rope where crevice corrosion at attachments or breaks in protective coatings may be severe (391), criteria for corrosion may be relatively easy to formulate based on reduction in areas.

More difficult to foresee, but demanding of further investigation, is the development of a criterion for resistance of wire rope to critically localized corrosion at tips of any cracks which may exist in component wires. This criterion would be in terms of the resistance of the individual wires to stress corrosion cracking (as discussed in section IA.3 for single wires), which in turn can be defined by K_{ISCC} (37), the critical stress intensity factor for fracture under corrosive environment, which is a function of the applied stress and the size of a crack.

3. Shock and Impact

No literature relating to a criterion for failure of wire rope under shock or impact loading was uncovered during this survey.

This area of investigation does seem to deserve attention especially when the conclusions of a survey (82) of problems associated with the Navy's use of wire rope reiterate the conclusions of the Naval Oceano-

graphic Office survey (failure analysis presented at beginning of this section), namely that impact loads are primarily responsible for the short lives of aircraft arresting gear.

1. Alekseev, N.I., "On the equilibirum shape and tension of a flexible string acted upon by external forces that are functions of the orientation of the string in space," J. Appl. Math. Mech. 28, 5, 1147-1150,, 1964. (Translation of Prikl. Mat. Mekh. 28, 5, 949-951, 1964 by Pergamon Press, Long Island City, New York, N.Y.).

x, y, z are the orthogonal Cartesian coordinates. F_x, F_y, F_z denote the projections of the load per unit length of string. Paper refers to the special case where F_x, F_y, F_z, are given functions of the direction cosines dx/ds, dy/ds, dz/ds. Author outlines the way which may lead, in this case, to the solution of the well-known differential equations of the problem, but the computation is not carried out to the very end.

AMR #5506 (1966)

2. Aluminized Wire Rope, "Advantages of Aluminized Wire Rope for Sea Water Service," Materials Engineering, page 30 (March 1968).

3. American Chain and Cable Co., "A Report on the Comparison of Bending Fatigue Properties and Physical Characteristics of Wire Rope with Polypropylene vs Sisal Cores," Project No. 2, Wilkes Barre, Pa., Jan 1967.

4. American Standards Association, "American Standard Definitions and General Standards for Wire and Cable," (approved Dec. 12, 1944) Sponsor: Electrical Standards Committee.

5. American Standards Association, "American Standard Specifications for Weather Resistant Saturants and Finishes for Aerial Rubber Insulated Wire and Cables," New York, 1939.

6. Anderson, G.F., "Tow cable loading functions," AIAA Journal 5, 2, 346-348 (Technical Notes), (Feb. 1967).

Paper presents a set of loading functions defining the fluid dynamic forces acting on a low-drag profile cable with pressure drag being negligible compared to total drag. Author considers the apparent change of Reynolds number for high towing velocities and deep submergence. Comparison with Eames loading function [Eames, M.C., "The configuration of a cable towing heavy submerged body from a surface vessel," Canada Naval Research Establishment, Dartmouth, N.S., Rept. Phx-103 (Nov. 1956)], shows little difference in normal loading, but the tangential loading differs substantially.

Author states that his analytical loading functions have similar

characteristics to those obtained by Clark ["Extension of underwater towing cable theory to high speeds," United Aircraft Corp. Research Labs., Rept. B110128-1 (Sept. 1963)], who used experimental wing data.

AMR #9774 (1967)

7. Antona, E., and Cereti, F., "Experimental analysis of the friction force in the aircraft control lines (in Italian)," Aerotecnica 43, 4, 141-152, Aug. 1963.

The behavior of the friction force in an aircraft control line forced to vibrate by external means is analysed.
The results of tests performed with different types of control lines, including the complete line for the ailerons of a FIAT G 91 aircraft, show that the vibratory motion can reduce the friction force to a very low level (only 1/10 of that in the nonvibratory condition).

AMR #2466 (1965)

8. Atwood, J.H. and Graham, J.R. "Moorings for the Offshore Oil Industry," Journal of Petroleum Technology, 20(6), 569-575 (June, 1958).

9. Austin, R.S. and S. Milligan, "Observations of Environmental Effects on a Deep Sea Acoustic Arry, Naval Underwater Ordnance Station, April 1964.

10. Author Unknown, "Notes on the Resistance of Rods, Cables and Ropes in Water" DTMB Report R-31, Dec. 1940

These notes discuss and review experiments on tow lines (resistance to towing and power required to tow manila rope, iron wire, insulated conductor, mine sweeping gear, etc.).

11. Author Unknown, "Tension in a Cable Towing a Heavy Weight through a Fluid" DTMB, Report R 33, March 1941.

This short report presents computations of tension in a 1/16-inch diam. stranded cable, 600 ft. long, towing a 300-lb. weight at speeds from 5 to 12 knots.

12. Avent, R.R., "Nonlinear field analysis of structural nets," Journal of the Structural Division, Proceedings of the American Society of Civil Engineers 95, ST 5, 889-907 (may 1969).

Subject paper gives a nonlinear analysis of arbitrary structural net

systems, that is, a net with irregular cable tensions, boundary conditions, and general loadings.

Solutions are given for three categories of nets: (1) a statically determinate network in which the final tensions are known, (2) an indeterminate (and nonlinear) system with a variation of loading, and (3) an indeterminate (and nonlinear) network with constant loadings but incremental cable prestresses. Numerical examples employing the "walk through" method and an associated interation procedure are presented to illustrate the use of results obtained in all three cases.

Procdure for analyzing an indeterminate system with horizontal boundry displacements due to an elastic supporting edge beam also is discussed.

AMR #903 (1970)

13. Babenko, A.F., "The determination of the terminal freely suspended load between the wires of a spirally wound cable (in Russian)," Nauch. Zap. Odessk. Politekh. In-t 27, 16-20, 1960; Ref. Zh. Mekh. no. 11, 1961, Rev. 11 V 426.

An investigation is made of the distribution of the forces between the wires of concentric rows of a spirally wound cable of 1 + 6 + 12 construction when the load is freely suspended. It is assumed that until the wires begin to interact they deform independently of each other, that the spirally wound cable works within the limits of elasticity and that the terminal load is distributed uniformly between the wires of a given concentric row. Each peripheral wire of the cable is considered to be a coiled spring with a big pitch for the winding; the theory of spiral springs is utilized for the determination of the axial elongation of the spirally wound cable. The author, working on the basis of the conditions that the terminal load is uniformly distributed between the wires of the given concentric row and that the linear displacements of the central and peripheral wires are identical, determines the forces in the wires of a spirally wound cable. A numerical example is furnished; this shows that until the wires commence to interact the freely suspended load on the spirally wound cable is distributed most irregularly between the wires.

AMR #718 (1964)

14. Bartlova, A., "The analysis of a non-loaded prestressed cable network (in Czech)," Stavebnicky Casopis 12, 4, 215-230, 1964

The prestressing forces acting in the cable network are obtained from the state of stress in an equivalent membrane by solving the homogeneous equations of equilibrium. The membrane surface is referred to curvilinear coordinates, the coordinate curves being identified with the cable network. Using an auxiliary function, the general equations

of membrane equilibrium are reduced to a system of two simultaneous first-order differential equations. The method is applied first of all to translation or rotational surfaces. In the case of flat roofs the authoress gives a comparison of her method with other known approximate solutions.

The paper is, in reviewer's opinion, suitable for design engineer, the results of the solved examples being presented in simple forms. The knowledge of the analytical geometry of surfaces will be assumed.

AMR #5294 (1965)

15. Basset, A.B., "On the Theory of Thin Wires", Proceedings, London Mathematical Society, Vol. 23, 1891-1892, pp. 105-127.

16. Batson, R.G., "Testing Wire and Wire Ropes", Testing, 1924, Vol. 1, pp. 7-22.

17. Battelle Memorial Inst., "Analytical and Experimental Investigation of Aircraft Arresting-Gear Purchase Cable," Final Report to the Naval Air Engineering Center (Contract No. N156-47939) Columbus, Ohio, July 1967.

18. Baud, R.V., and Meyer, J.," Magnetic testing of structural cables (in German)," Schweiz. Arch. 21, 404-410, Dec. 1955.

AMR #1833 (1956)

19. Bauer, F.," Approximate calculation of decrease of tension in prestressing steel wire wound on circular cylindrical sheel containers (in German)," Beton u. Stahlbeton. 50, 11, 287-290, Nov. 1955.

The wall of cylindrical reinforced-concrete shell containers is often reinforced by prestressing steel wire wound on it. Forces transmitted by the prestressing wire to the cylinder wall reduce the radius of the latter, whereby a reduction of tension is caused in the coils of wire already applied. The paper presents an approximate calculation of this reduction of stress.

Start is made from an intermediate phase of the winding, when it has been completed only up to a certain height. It is established what reduction Δw_1 of the radius of the cylinder mantle would take place if the winding were completed right to the end and, during this, the prestressing wire invariably preserved its initial tension. However, because of the radius reduction Δw_1, reduction of tension Δp_1 takes place in the prestressing wire at the height examined. It is

supposed that a similar reduction of tension occurs in the windings of the prestressing wire above the place investigated. This modifies the value of Δw_1 previously calculated, and, accordingly, the above value of Δp_1 has to be corrected by some magnitude Δp_2. This procedure may be continued and, for the reduction of tension sought, the approximate value of $\Delta p_1 + \Delta p_2 + \ldots + \Delta p_i^* + \ldots$ may be obtained. Though the above approximation does not converge toward the precise solution, the rough approximation does not differ much in practical cases from the precise value, as shown by a comparative calculation executed.

The paper closes with a tabulation of formulas of ordinates of determation and moment influence diagrams for different simple conditions of support in the calculation of infinitely long cylindrical shell containers.

AMR #1794 (1956)

20. Beebe, K.E., "Mooring Cable Forces Caused by Wave Action on Floating Structures" College of Engineering, University of California (Berkeley) Series 3 - Issue 366, June 1954.

The report presents experimental data on forces on mooring cables caused by wave action on floating structures. Quantitative measurments were made of the horizontal cable force exerted by the mooring cable on a force meter at the bottom, the surface time history of the waves transmitted past the structure, and the surface time history of the waves without the model in the water.

21. Berkson, W.G. and R.J. Wolfe, "Investigation of Specially Constructed Tow and Power Cables and Associated Equipment for use in Torpedo Countermeasures," New York Naval Shipyard, Material Lab., Dec. 1960.

22. Bert, Dr. C.W. and Stein, R.A., "Stress Analysis of Wire Rope in Torsion and Tension", Wire and Wire Prod., May 1962, Vol. 37, No 5, 621-624; Jun. 1962, Vol. 37 No 6, 769-772.

23. Berteaux, H.O., "Introduction to the Statics of Single Point Moored Buoy System," WHOI Tech. Pub. (in press).

24. Berteaux, H.O., "Surface Moorings, Review of Performance" Reference No. 68-20, Woods Hole, Mass., March 1968.

A brief history of moorings is presented. The possible types of failures are reviewed. A theory which could explain the failure of the wire ropes is presented. This report is quite interesting from

a materials viewpoint.

25. Berteaux, H.O.; E.A. Capadona; R. Mitchel and R.L. Morey "Experimental Evidence on the Modes and Probable Causes of a Deep-Sea Bouy Mooring Line Failure: Transactions of the 4th Annual MTS Conference, Washington, D.C. (8-10 July 1968).

This paper presents the case history of an instrumented buoy system found adrift and recovered from the Atlantic Ocean. It describes the mechanical and metallurgical tests performed on the mooring line in an attempt to establish the modes of failure of this typical deep-sea mooring. Present (1968) engineering efforts accomplished at or with the Woods Hole Oceanographic Institution are outlined.

26. Bethlehem Wire Rope, Bethlehem Steel Corp., Catalog 2305, Bethlehem, Pa.

27. Blatherwick, A.A.," Stress redistribution during bending fatigue," Experimental Mech. 1, 4, 128-135, Apr. 1961.

Paper deals with distribution of stress in a bending-fatigue specimen and its redistribution during fatigue resulting from change in the cyclic modulus of the material. Because of this effect the results of fatigue tests vary depending upon the loading considered - constrant-strain, constant-stress, and constant-moment - it is shown that the last one is intermediate between the other two extremes. A machine specially developed for investigation and the test-procedure followed are described The results obtained are discussed and compared with calculated values based on cyclic stress-strain curves obtained independently in axial stress tests. Author is conscious of the limitations of the tests and the materials chosen, nevertheless, he has ventured to arrive at general conclusions which, in reviewer's opinion, may be taken as indicative rather than as affirmative. AMR 12(1959), Rev. 2923 may be seen for author's earlier work in joint authorship.

AMR #3318 (1962)

28. Bohmer, J.F.," The exact curvature of pretensioning cable (in Danish)," Tekn. Skr. no. 14 N, 11 pp., 195[illegible]

Author deals with the problem of determining the exact curvature of the pretensioning cable which, owing to uniform distributed load, will give momentless stress distribution throughout the beam.

This curvature is, in the literature, supposed to be the circle as well as the parabola of the second order. Obviously, the exact curve cannot ... these, even if the difference cannot be great. Because of the constant force in this cable, it would have to be raised a little compared with the parabola. On the other hand, the vertical component of S must not exceed the shear force in the section, so the curve is strictly limited.

The differential equations are established assuming no friction at the pretensioning, and solutions are found by successive approximations.

By taking friction into account, additional correction terms are found. The corrections are small, 5-10% each. It can be concluded that this must be the case even for more complicated constructions, e.g., continuous beams.

Further, the moments are very small when the vertical component of S is of the same magnitude as the shear in the section.

Practically, the theoretical curve is not of great importance because usually both change of load intensity and distribtuion occur, thus giving moments.

By proper selection, however, of the two variables, the magnitude of the pretensioning force and its eccentricity, any two extreme moments can be taken by a section with stresses chosen.

Stress concentrations may be taken by additional nonprestressed reinforcement.

AMR #126 (1958)

29. Bolcskei, E., "High-Tensile steel cable tie-rods," Extracts from Scientific Works of the Chair no. 2 of Bridge Construction (Epitoipari es Kozlekedesi Muszaki Egyetem. Tudomanyos Kozlemenyei), Budapset, 1957, 29-40.

AMR #4949 (1958)

30. Bollenrath, F. and Bungardt, W., "Effect of Surface Decarburization and Heat-Treatment on the Fatigue Strength and Time-Resistance of Steel Stay-Wires. F. Bollenrath and W. Bungardt. (Archiv fur das Eisenhuttenwesen 1938, Vol. 12. Oct., pp. 213-218). In a previous paper by F. Bollenrath and H. Cornelius (see Stahl und Eisen, 1938, Vol. 58. Mar. 3, pp. 241-245) time resistance was defined as the capacity of a material to withstand a limited number of reversed stresses above the fatigue strength until fracture supervenes. In this paper they describe an investigation of the effect of decarburization on the strength of steel wires, the results ... (1) The fatigue strength of patented unalloyed steel wire was reduced by surface decarburization; (2) alternating bend and alternating torsion test showed that the life of steel wire was also reduced by decarburization; (3) the alternating bend strength of both unalloyed and chromium-molybdenum steel wire was improved by tempering at about 250 ... after cold-working; (4) subjecting round specimens to

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fluctuating tensile stresses and to torsional vibration showed that decarburization had a deleterious effect upon both the time resistance and the fatigue strength; (5) chromium-molybdenum steel had, especially when heat-treated, a fatigue strength greater than that of unalloyed steel; and (6) by using wire of special cross-section it is possible to make better use of the advantages of alloyed steel in aeroplane construction, and so obtain not only a greater margin of safety but also a decrease in weight.

31. Brauer, H., "The Damping of Wires," Metallwirtschaft, <u>18</u>, June 16, 1939, pp. 503-505.

32. Brewer, G., "Residual Stresses in Wire Loops at Anchorage Shoes or Grommets," Metals Progress, Vol. 44, Sept 1943, pp. 441-447.

Examined failures of heat treated bridge wires forming main cables of two suspension bridges in terms of the residual stresses developed when wires are preformed to fit around the anchorage shoes. Indicates the fallacy in assuming that becase the wires just fit around the anchorage, there are no stresses in the wires. Actually, the author considered, the preformed loop contained such high residual stresses that a relatively small superimposed direct stress in tension brought the extreme fibers up to the elastic limit. Author explained that the difference in ductility between the cold-drawn and heat treated wire allowed the cold drawn wire to deform plastically and relieve the residual stress. In addition the increased notch sensitivity of the heat treated wire compounded the effect of the high initial stresses resulting in an early failure.

33. Brezina, V., "Theory of a Jens-shaped cable roof anchored in a plane ring (in English)," Rozpravy Ceskoslovenske Akademic Ved, Rada Technickych Ved 76, 2 103 pp. (1966).

The stresses in a Cartesian network of cables supporting a bicycle-wheel roof on an elliptic plan are determined by setting the nonlinear equations for the membrane stresses in the equivalent membranes. The equations consider dead and snow loads, prestressing, thermal changes, and the state of stress due to the deformation of the ring. The simplified equations corresponding to small deformations are obtained, and the linearized equations derived from the small deformation equations are solved. The optimal bending rigidity of the ring is considered in order to minimize the moments in the elliptic ring while guaranteeing its buckling stability. The stresses in the membranes are obtained under a sequential application of the loads corresponding to the actual construction technique. The difference equations adapted to a more realistic solution by means of computer also are derived.

AMR #3944 (1967)

34. Brock, J.E., "Matrix analysis of flexible filaments," Proc. First U.S. nat. Congr. Appl. Mech., June 1951; J.W. Edwards, Ann Arbor, Mich., 285-289, 1952.

By matrix algebra, an expression for the deflection of the end of an elastic filament is found for generalized force system at that end. In order to facilitate the mathematics, the equation of the curve of the filament is defined as a position vector. Small deflection theory is used and the cross-section variation is assumed to be gentle along the length of the filament. The method is applied to a helical wire for illustration, with several types of wire section properties used, including rectangles and circles.

AMR #3507 (1954)

35. Broschat, M. and T.E. Sherman, "A Five Year Field Study of Armor Rods and Conductor Vibration Fatigue," IEEE Summer Power Meeting, New Orleans, La., July 10-15, 1966, Paper No. 33, pp. 86-399.

36. Broschat, M. and T.E. Sherman, "Neoprene Curshion May Answer Conductor Fatigue Problems," Electric Light and Power, Dec. 1967.

37. Brown, B.F., "Coping with the problem of the stress-corrosion cracking of structural alloys in seawater," Ocean Engineering 1, 3, 291-296 (Feb. 1969).

In the area of developing ocean technology, the focus of concern with respect to corrosion has shifted from general wastage to critically localized corrosion. As increasingly stronger alloys are used in seawater, one of the most important forms of critical corrosion is stress-corrosion cracking. Methods for quantifying this property are discussed, and the implication of the measured quantities to materials selection are indicated.

AMR #9527 (1969)

38. Buchholdt, H.A., "Deformation of prestressed cable-nets (in English)," Acta Polytechnica Scandinavica Civil Engineering and Building Construction Series no. Ci 38, 17 pp. (1966).

Literature on the deformations of suspended roofs of cable-nets or skeleta assemblies consisting purely of link-bars is not very wide.. Author attempts this problem by using the "Method of Potential" applied to the deformation characteristics of a cable-net, prestressed initially

to sufficient magnitude; his assumptions are: (1) cables cannot resist bending; and (2) linear elastic behavior of the length of the cables between any two joints exists. The net is treated as a "mechanism" and the total potential of the system minimized for a stable equilibrium-configuration. The gradient vector $\partial \bar{W}/\partial x$ representing the unbalanced forces in the X, Y, and Z directions for a given displacement vector [x] would represent the direction of greatest increase of the total potential. From the out-of-balance force set expressed in an Euclidean norm $R = [\partial \bar{W}/\partial x_k]^T[\partial \bar{W}/\partial x_k]^{1/2}$, a unit vector V_k in the direction of the steepest descent of the total potential surface is obtained; tp minimize the total potential, a distance of S in the direction $[V_k]$ is moved, with successive iterations resulting ultimately in a displacement vector for which R can be made negligible, which corresponds to a most stable configuration of a net under initial and applied forces. The energy expression for the total potential is a fourth-order polynomial in terms of S, the five constants being evaluated in terms of E, A, L and displacement vectors and $d\bar{W}/ds = 0$ for the solution of the problem.

Computer solution of a numerical problem is shown. Important conclusions are: (1) displacements decrease, with increase of prestressing and with increase of selfweight, but increase with decrease of curvature; (2) load displacement relations are nonlinear.

Paper is a welcome contribution to an otherwise seemingly intractable problem.

AMR #3359 (1967)

39. Buhler, H., "Influence of the Shape of the Die on the Internal Stresses and Strength Properties of Cold-Drawn Steel Rods," ("Archiv fur das Eisenhuttenwesen, Vol. 8, April 1935, pp. 465-466).

In experiments on samples of steels St. 37 and St.60, cylindrical dies produced relatively high stresses in the rod. Steep dies produced principally a deformation of the surface; thus, for instance, bright drawing with a steep die produced a material with very much lower stresses than did the usual type of die; with steep dies the power consumption was generally higher. On account of the bad frictional conditions, the cylindrical die required by far the greatest amount of power. A normal die produced a smooth and unexceptionable surface, whereas that from a cylindrical was streaky and porous. For particularly smooth surface at low drafts, the use of a steep die is recommended. As the steepness of the die increases, the tensile strength and yield point of the rod increase, the latter more rapidly than the former. Any influence of the die on the elongation and reduction of area could not be observed.

40. Buhler, H., and Kreher, P.J.," Simple method to determine the internal stresses in wire (in German)," Archiv fur das Eisenhuttenwesen 39, 7, 545-551 (July 1968).

Authors describe a cross-slot method to measure the longitudinal internal stresses in cold-drawn wires. By this method, the wire is slotted in a cross sectional plane to the center and the deflection of the wire is measured with dial gages or with an optical method. The derived equations to calculate the internal stresses are valid for a linear uniaxial and a rotation-symmetrical stress condition. The influence of the slot width on the deflection is shown by tests on wires with 0.8% carbon, cold-drawn with a reduction of cross sectional area of 0.8 to 32.4% on a diameter of 5 mm. The application of the method and the determination of the longitudinal residual stresses in the surface layer is further shown by tests on wires with 0.1% carbon, cold-drawn with a reduction of cross sectional area of 0.8 to 40% on a final diameter of 5 mm.

AMR #6139 (1969)

41. Bullen, N.I., "The influence of rope stretch on tension variations in arresting gears," Aero. Res. Counc. Lond. Rep. Mem. 2964, 38 pp., 1956.

Equations of motion are set up for a system consisting of an aircraft and an arresting gear. The analysis differs from work previously done by the assumption of elasticity, mass, and friction in the wire cable used. The resulting equations are integrated step by step. Comparison of the results with observed rope tensions and accelerations indicates good agreement, and it is concluded that the rope elasticity accounts for hitherto unexplained observed oscillations in rope tensions.

AMR #1048 (1957)

42. Busby, R.F., L.M. Hunt and W. Rainnie, "Hazards of the Deep," Ocean Industry, Vol. 3, No. 7, July 1968.

Two kinds of hazards are considered: (1) Man-made hazards (cables, wrecks, etc.) and (2) natural hazards (see state, currents, topography, etc.). The first hazard mentioned are cables. Submarine cables may be used for power, communication, mooring or a combination of these functions. Cables may also exist as lost or discarded material.

43. Cables, Connectors and Penetrators, "Meeting on Cables, Connectors and Penetrators for Deep Sea Vehicles", Department of the Navy, held at Management Information Center, Deep Submergence Systems Project Office, Bethesda Md., 15-16 Jan. 1969; minutes of

44. Capadona, E.A., "Dynamic Testing Predicts Marine Cable Failures," UNDERSEA Technology, Oct. 1967.

The author discusses the value of laboratory studies on particular problems of dynamic loading in cables for oceanographic applications. Noted analogies between dynamic problems in power industry and those in underseas applications. Specific problems mentioned are: (1) repeated axial loading; (2) strumming; (3) dancing; (4) shock loads; and (5) sheave studies (ababrasion, fuelting, radial compressure forces, bending stresses over sheaves). No data given - no specific tests mentioned.

45. Capadona, E.A. and W. Colletti, "Establishing Test Parameter for Evaluation and Design of Cable and Fittings for VDS Towed Systems," The New Thrust Seaward, Transactions of the 3rd Annual MTS Conference, San Diego, California, June 5-7, 1967.

46. Chapman, R.W., "The Stress of Wire Ropes due to Bending," Engineering Review, October, 1908.

47. Chase, L., "Causes of Breaks in Wire Rope and Cable in Oceanographic Applications," Naval Oceanographic Office, Instrumentation Department, Washing, D.C.

48. Chade, L. "Why Wire Rope Breaks and How to Prevent It," Ocean Industry, May 1969, pp. 98-102.

Results of US Naval Oceanographic Office Survey to determine causes of failures including partings and breakages.

49. Chelton, H.M., "Wire Rope," Pit and Quarry, 43, 80 (March 1968).

50. Chistopherson, D.G., and Naylor, H.," Promotion of fluid lubrication in wire drawing," Instn. mech. Engrs. Proc. 169,35, 643-653, 1955.

A factor limiting the rate at which wire can be drawn through a die is the severe die wear which may occur at high speed. If hydrodynamic lubrication could be induced, wear would probably be much reduced. It is suggested that this can be done by supplying oil to the die entry at a pressure comparable with the wire yield stress. The necessary pressure can be conveniently generated by causing the wire to approach the die through a tube of slightly larger diameter than the wire, sealed on to the inlet side of the die.

Experiments showed that the die friction is thereby so reduced that, even allowing for the drag in the tube, the total drawing force is less than with existing methods of soap lubrication; and tests

with steel dies have shown large reductions in wear. A theory of the behavoir of the wire in the inlet tube and of the temperature distribution in the system is included. The former is based on the hypothesis that the wire follows that path in the tube which leads to minimum power dissipation, assuming laminar viscous flow; the experimental results are consistent withit.

Reviewer belives that this is a most important investigation, both from a practical viewpoint and as an interesting new application of the variational principle to viscous flow.

AMR # 3627 (1956)

51. Clarke, N.W.B.,"Measuring loads in wires: two simple devices to ensure accuracy in prestressing," Engineering 177, 4613, 812-815, June 1954.

Two simple methods for measuring total loads in prestressing wires are described: (1) Use of a very stiff double cantilever steel spring together with a dial gage to measure the deformation of the spring; (2) use of a lever loaded with known weights.

AMR 1346 (1955)

52. Clarke, N.W.B., and Walley F.,"Creep of high-tensile steel wire," Proc. Instn. Civ. Engrs. 2, part 1, 107-135, Mar. 1953.

Paper gives results of engineering rather than fundamental importance on the stress-relaxation of "high tensile strength steel"wire stretched and maintained at constant length. Greater stress relaxation was found at higher initial stress levels. At any initially applied stress, the stress relaxation was proportional to log time up to 1000 hr, the time limit of tests.

AMR # 3735 (Dec 1953)

53. Cleaver, F T , and Miller, H., " Wire-drawing technique and equipment," London, Inst. Metals, "The cold working of non-ferrous metals and alloys," 51-106, 1952. $2 50.

The principal landmarks in the development of the wire-drawing industry in this country from the earliest beginnings until the present time are reviewed. A description is then given of present-day machines, comprising tandem - and cone-type machines, in which slipping of the wire occurs in the course of drawing, and also the nonslip variety. Die design, die materials, lubricants, speeds of drawing, reductions, and other aspects of wire drawing are dealt with, and a detailed account is given of current practice

in the production of copper, brass, bronze, and other copper-alloy wires, and also of aluminum and alloy wires. Finally, various types of defects which are encountered are considered.

AMR #2818 (Sept 1953)

54. Cole, J.D., C.B. Dougherty and J.H. Huth, "Constant-Strain Waves in Strings," J. App. Mech., ASME, Vol. 75, pp. 519-522, 1953.

55. Conducting Cable, "More Conductor in the Cable," Electl. Rev., Lond., Vol. 184, No. 2, 53 (1969) Jan.

600/1000 V 'Alplast' cables developed by the Hungarian Cable Works have the economic advantage of a concentric neutral arrangement, but are easier to handle and have better resistance to corrosion. They have solid Al conductors, pvc insulated and sheathed. The neutral is, in effect, 4 separate conductors, 3 in the interstices between the phase conductors plus a helically wound Al tape overall. The cross section of the 4 neutral conductors is thermally equivalent to each of the 3 phase conductors. The larger cables have specially shaped phase and neutral conductors to provide an even better 'space factor' in the cable. Cross sections are shown. The cable is intended to have welded joints. --AA

Source: Corrosion Abstracts, Vol. 8 No. 6, p. 412, line 68, Nov. 1969.

56. Cornelius, H. and Bollenrath, F, "The Notch Sensitivity of Cold Worked Steels when Subjected to Bending, Fatigue", Archiv fur das Eisenhuttenwesen, 1940, Vol. 14, Dec., pp. 289-292.

Found that notch sensitivity increased with degree of cold work for: (a) soft iron; (b) chromium-molybdenum heat treatable steel; and (c) carburized anstentic steels. For .38% C steel the effect was reversed slightly (more marked for Cr-Ni-Mo heat treatable steel). Carburized anstentitic steel had no notch sensitivity in the soft state and only a slight one when cold-worked.

57. Corton, H.T, and Sinclair, G.M., "A Wire Fatigue Machine for Investigation of the Influence of Complex Stress Histories," American Society of Testing Materials Preprint No. 67, 1956.

A wire fatigue testing machine described which operates on the principle of a deflected rotating Strut. Results of constant stress amplitude tests of steel wire are presented and statistically analyzed.

58. Craggs, J.W.,"Wave motion in plastic-elastic strings," J. Mech. Phys. Solids 2, 4, 286-295, June 1954.

59. Cristescu, N. "Dynamic Plasticity," Applied Mechanics Reviews, Feature Article, Vol. 21, No. 7, July 1968.

60. Curry, J.H. and Posner J., "Results of Experiments with Models of High Speed Towing Targets including Estimates of Full Scale Target Drag and cable Tension," DTMB Report No. 595, Nov. 1947.

61. Curtis, A.R., and Cowan, H.J.,"Design of longitudinal cables in circumferentially wound prestressed concrete tanks," Mag. Concr. Res. no. 15, 123-126, Mar. 1954.

Expressions are derived for longitudinal bending stresses created by (and during) the circumferential prestress process. Paper includes expressions for minimum longitudinal prestress required to prevent cracking.

AMR #3553 (1954)

62. Czitary, E.,"Behavior of a cable on a pulley with elastically deformable lining (in German),"Ost. Ing.-Arch. 10, 4, 349-359, 1956.

Problem deals with a cable stretched, say horizontally, between two fixed points and loaded vertically at the middle through a pulley with an elastically deformable lining around its circumference, a finite portion of the lining being thus compressed and brought in contact with cable. Maximum slope of cable is assumed to be small. In addition to the main problem in which flexural rigidity EJ of cable is considered, a special case in which EJ is neglected is also discussed. Then, in two other special cases of considering and neglecting EJ of calbe, respectively, a rigid pulley without lining is considered. Obtained for all cases are expressions for determining length of contact between cable and pulley, elevation of pulley, minimum radius of curvature ρ_0 of cable, and maximum pressure σ_0 between cable and pulley, the last two quantities occurring at center of cable. Numerical example shows much larger ρ_0 for the cases of pulley with elastic lining than for those of rigid pulley without lining; use of lining such as that made of rubber is therefore justified.

Reviewer likes to point out that author's differential equations governing deflections of compressed and free portions of cable in main problem are similar to those for beams under simultaneous axial and transverse loading, with and without an elastic foundation, respectively, because EJ of cable is considered; and that, when pulley has elastic lining, the numerical results show little difference between considering and neglecting EJ of cable, indicating that EJ

may well be neglected to have much simpler calculation. In the first unnumbered equation in paper, for computing the moment in cable, term Px_o should be $P(x_o + x)$, but the error fortunately does not affect the rest of the calculation.

AMR #1748 (1957)

63. Czitary, E., "Behavor of a cable riding on an easticaliy coated roller (in French)," Ann. Ponts Chauss. 127, 6, 795-820, Nov.-Dec. 1957.

It is common practice to deflect or bend a cable by means of a roller. An elastic coating in the groove of the roller, e.g. a rubber coating, can reduce the cuvature of the cable. Paper presents detailed calculations of effect of coating on curvature and stress of cable including conditions which must be satisfied by the coating. Originally by E. Czitary [AMR 10 (1957), Rev. 1748], paper was translated into French by L. Lehanneur. Translator added section which covers an instance not considered by Czitary, and also presents a simpler method of computing curvature.

AMR #807 (1959)

64. Czitary, E., Suspended-cable transport devices [Seilschwebebahnen], 2nd edition Wien, Springer-Verlag, 1962, vii + 467 pp. $27.59.

Author condenses a lifetime's experience in this field. Book is a complete exposition of theory and engineering practice for design and installation of cable transportation devices. Introductory definitions and classifications are followed by treatment of various types of wire ropes. Methods are presented for determination of loads on supporting and traction cables. Spearate sections treat construction of cable supports, loading stations, carriages, or other carrying services, and safety features. A separate portion is devoted to ski lifts. The extensive and complete bibliography extends back to 1906, and contains about 350 entries in various languages.

A necessary text, not only in this field, but also wherever cables are used for suspension of loads.

AMR #4439 (1963)

65. Czyzewski, M., "The friction coefficient between rope and sheave in a lift (in Polish)," Archiwum Budowy Maszyn 13, 1, 31-70 (1966).

The value of the apparent coefficient of friction between rope and sheave depends on the geometrical form of the groove, the pressure distribution between the rope and the groove, and the value of the real coefficient of friction between them. The distribution law of the pressure has been determined on the basis of wear tests of grooves. These tests have shown that an undercut groove becomes

elliptic as a result of wear and have enabled the determination of the parameters of the ellipses describing the profile of a worn groove. On the ground of a new hypothesis of pressure distribution established by means of an experimental study of the wear process, theoretical relations are obtained for the determination of the apparent friction coefficient in usual semicircular undercut and elliptic undercut grooves.

Experimental investigation of the apparent friction coefficient carried out by means of laboratory test stand and an experimental lift have confirmed the correctness of the theoretical relations obtained and enabled the determination of the minimum values of these coefficients, for the purpose of compution of the safe value of the friction coupling between the rope and the sheave.

The above new method for determining the apparent friction coefficients in undercut grooves enables correct interpretation of the results of other investigations. For practical purposes some simplified equations are proposed.

AMR #9059 (1968)

66. Daeves, K., "The Influence of Hoisting Frequency, Construction, and Material on the Durability of Wire Ropes," Draht, Germain ed., 1954, 5, Feb., pp. 45-49.

Rope life, based on colliery statistics shown to vary inversely with number of working cycles per month. For a given hoisting frequency the number of failed wires increases logarithmically with time. Effects of construction and material pronounced when hoisting frequency high. Endurance limit discovered to increase with frequency of rests for a given stress amplitude.

67. Daeves, K., Gerold, E., and Schulz, E.H., "Influencing the Life of Fatigue Stressed Parts by Periods of Rest", Stahl and Eisen, 1940, Vol. 60, Feb. 1, pp. 100-103.

Stresses applied above the fatigue limit at certain time intervals and temperatures. Showed; (1) that rest increased the life above the fatigue limit; (2) that the increase was greater the sooner cycling was started after rest; (3) greatest recovery for coarse pearlitic structure and decarburized surface. These conclusions should be considered in fatigue tests which are intended to simulate particular load histories.

68. Dale, J.R., "A Force Balance Analog for Determining Characteristics of Ocean Cable Systems," Report No. NADC-AE-6517, 16 Nov. 1965.

69. Dale, J.R. and J.M. McCandless, "Determination of Normal Drag Coefficients for Flexible Cables," Report No. NADC-AE-6719, June 1967.

70. Davenport, A.G., "Dynamic behavior of massive guy cables," Pro. Amer. Soc. Civil Engrs. 91, ST 2 (J. Struct. Div.) (Part 1), 43-70, Apr. 1965.

An equation for small displacement dynamic guy moduli of long guy cables, including air-resistance damping terms, is derived. Uniform cable tension is assumed and a parabolic approximation of the catenary is used. Horizontal sinusoidal excitation in the form of upper guy end displacement, both in the plane of the guy and perpendicular to it, is considered. Modulus due to the latter is found to be negligible when compared with the former. In-phase and out-of-phase components of guy modulus (author fails to clearly identify them so) are plotted against frequency for several critical damping ratios and a guy inclination angle which the author fails to give.

Experimental results obtained from model guys gave fair agreement with theoretical results for small periodic guy end displacements to frequencies approximately four times the fundamental frequency for the undamped taut wire.

Paper should provide designers of guyed structures with valuable concepts concerning the dynamic behavior of their structures.

AMR #816 (1966)

71. Davidson, A.E., J.A. Ingles and U.M. Martinoff "Vibration and Fatigue in Electrical Conductors," Trans. AIEE, Vol. 51, pp. 1047-1051, Dec. 1932.

72. Davidsson, W., "Investigation and calculation of the remaining tensile strength in wire ropes with broken wires," Acta Polyt. 174 (Mechanical Engineering Series 3, no. 6), 38 pp., 1955.

The remaining tensile strength P_{ds}, as estimated by static tensile test of a straight rope, is not adequate to serve as a starting point for judging whether a rope should be discarded or not. In this respect the remaining bending tensile strength P_{bdr}, which is obtained by bending the rope over a pulley when in movement and under a load, should be decisive. For ropes with two layers of wires in the stands, covered by the investigation, $P_{bdr}/P_{ds} \approx 0.78$ may be set in the case of moderate weakening owing to wire breaks and wear.

The wire recovery length has been investigated in static remaining tensile strength tests. Here, among other things, it is proved that the wire recovery length is not equally great for the different layers of wire in the strands. Thus for ropes with two layers of wires in the strands the wire recovery length in the inner layer was only about half that of the outer one.

AMR #415 (1956)

73. Davidsson, W.,"Investigation and calculation of the remaining tensile strength in wire ropes with broken wires (in English)," IngenVetenskAkad., Stockholm no. 214, 38 pp., 1955.

The remaining tensile strength P_{ds}, as estimated by static tensile test of a straight rope, is not adequate to serve as a starting point for judging whether a rope should be discarded or not. In this respect the remaining bending tensile strength P_{bdr} which is obtained by bending the rope over a pulley when in movement and under a load should be decisive. For ropes with two layers of wires in the strands covered by the investigation, $P_{bdr}/P_{ds} \approx 0.78$ may be set in the case of moderate weakening owing to wire breaks and wear.

The wire recovery length has been investigated in static remaining tensile strength tests. Here, among other things, it proved that the wire recovery length is not equally great for the different layers of wires in the strands the wire recovery length in the inner layer was only about half that of the outer one.

A method is given for calculating the weakening due to wire breaks and wear of the tensile strength of a rope which is still in use.

Some fifty discarded crane, lift and telpher ropes have been investigated with regard to the occurrence and distribution of invisible wire breaks

Finally, the advisability of choosing the rope lay as the control length is pointed out.

AMR #2040 (1958)

74. Davis, E.A. and Dokos, S.S., "Theory of Wire Drawing," J. Applied Mech., Vol. 11, pp. 193-198 (1944).

75. Dean, D.L.," Static and dynamic analysis of guy cables," Proc. Amer. Soc. Civ. Engrs. 87, ST 1 (J. Struct. Div.), 1-21, Jan. 1961.

Author proposes to analyze tower guy cables for static and dynamic conditions in a more exact manner than has been previously done, but without introducing additonal complexity into the solution. The vibrations of the tower normal to is axis and the resulting motion of the end of the cable attached to the tower are considered.

The wisdom of some simplifying assumptions used by the author have been questioned in published discussions of the paper (for example, see; discussion by G.V. Berg, Proc. Amer. Soc. Civ. Engrs. 87, ST 4, p. 61-65). One of the main points questioned is treatment of the horizontal component of the cable tension which is first assumed constant and later given as a function of time. Persons interested in the subject should also consult the author's closing discussion which will be published in the future.

AMR #697 (1962)

76. Dean, D.L., and Ugarte,C.P.,"Analysis of Structural Nets"(in English),Publ. Internat. Assoc. Bridge Struct. Engng.,23,71-90,1963.

Expressions for the relation between deflections and loading for structural cable networks are developed. Solutions are found for doubly threaded nets with quadrilateral and triangular boundaries; also solutions are given for the cases of quadruply threaded nets. Transformation of coordinates and the application of Green's functions are discussed in the appendices. Pertinent comments relative to the practical aspects of manual and machine computations are given.

AMR #6984 (1964)

77. Deforest, A.U. and Hopkins, L.W., "The Testing of Wire Rope and Rope Wire,"American Society of Testing Material, 1932.

Requirements for endurance tests are given in terms of the location of the maximum stress, length of the stessed portion, frequency of the stress and wire shape. Criterion for the end of a test is given in terms of number of wire breaks occuring in a foot. Breaks are classified according to location within the rope of the break. A warning is given that stress analyses must take into account changing conditions within the rope.

78. Derevinskii, I.L., "The Determination of the "pull" and the Figure for the Equilibrium of a Wire-Wove Cable in Space Under the Action of the Forces of Gravity and Aerodynamic Loads," (in Russian) Trudi Karagandinsk. Gorn. In-ta no. 2, 245-267, 1958; Ref Zh. Mekh. no. 2, 1960, Rev. 1606.

The problem given in the title is investigated while making the assumptions that the aerodynamic load is directed along the projection of the velocity onto the plane normal to the wires and that its intensity is determinable by the formula $n_o(\sin\phi - k\cos\phi)$, where n_0 and k are constants, while no depends on the velocity of the flow, horizontal and constant along the cable and ϕ is the angle of attack. With these assumptions, the problem merges with the solution of a linear equation.

AMR #2988 (1962)

79. de Silveira, Feijo A. H., "Examination of a Steel Cable," Bol. Int., 1953, 4, Jan, pp 12-29 (in Portugese).

Examination of an apparent fatigue failure of a carbon steel cable which had caused an accident on the Pao de Acuar (Sugar Loaf Mtn in Rio de Janeiro). Bend tests produced failure of the rope in nine (9) cycles.

80. Dinnik, A.N.," Papers on the mining industry (in Russian)," Mascow, Ugletekhizdat, 1957, 195 pp. + illus. 6r. 90K; Ref. Zh. Mekh. no. 3, 1958, Rev. 3303.

Papers included in the compendium deal with various matters concerning the mining industry: the application of the theory of elasticity to the solution of problems related to management of mine roofs; the dynamic stresses in hauling cables; the strength of hauling cables, the danger of resonance in winding machinery equipped with bicylindro-conical drums, the distortion of mine shafts, etc. The compendium does not include papers bearing on the subject published by A.N. Dinnik, as for instance: On the vibration of wire of varying toughness [Izv. Ekaterinoslavsk. Gorn. In-ta, 1914, no. 1]; Dynamic stresses in a hauling cable when the top end unexpectedly stops [Yuzh, Inzhener, 1917, nos. 3, 4]; Dynamic stresses in a hauling cable during an evenly accelerated motion of its top end [Byul. Ekaternoslavsk, Gorn. In-ta, 1918]; Dynamic stresses in a hauling cable [Nauka na Ukrine, 1922[.

AMR #4880 (1959)

81. Diratsu, V.S.,"Determination of stresses in the strands of spirally wound steel cables by the electromagnetic method (in Russian)," Nauch. zap. Odessk. politekn, in-ta 1, 65-82, 1953; Ref. Zh, Mekh. no. 12, 1956, Rev. 8689.

The study is experimental and is devoted to the determination of the distribution of load between the separate layers of wire-wound cables, simply twisted under the influence of stretching by the load, producing plastic deformation of the wires. Investigation was carried out on samples of double layer cables of two types: (1) having equal angles of hoist of the wires in the windings, (2) having identical pitch in the twist. The test method is based on the change of the magnetic properties of the wire as the result of plastic deformations. The formation of the magneto-mechanical characteristics of the wires was accomplished by means of the comparison of the losses on the reversal of magnetism in the sample and in the calibration standard. Tests were made both on the whole cable and on the separate windings. The results of the investigation permit the deduction to be made on the more even distribution of loading between the separate wires of the cable, arising from the condition of the equality of the angles of twist of the wires in the separate windings, by comparison with cables

having identical pitch in the twist of the wires of the windings.

AMR #3488 (1958)

82. Dodson, M,; Veazie, W.H.; Fries, R.H.; Gibson, P.T.; and Cress, H.A., "Investigation of Wire Rope Service Requirements and Design Parameters," Final Report to Naval Ship Systems Command, Department of the Navy (Contract No. N-00014-68-C-0492) ONR - 291-015/5-6-68 (Code 485), August 29, 1968, Battelle Memorial Institute, Columbus Laboratories).

Designed as overall picture of Navy's use of wire rope and to provide understanding of problems being encountered in the areas of physical hazard with failure in operational equipment, loss of time and material, and increasing costs of wire rope. Visits to Naval Shipyards and other installations which use wire rope - to discuss problems. Reviewed wire rope research and testing programs conducted by Naval Laboratories. Review of basic specifications. Study of Supply System and design criteria. Recommended solutions to problems. Some conclusions were: (a) specifications are not adequate to uniquely specify a wire rope, (b) design specifications are outdated and are based on incorrect assumptions, (c) lubrication practices are non-uniform and often lubrication is improperly performed or neglected, (d) standardization of equipment is virtually non-existent; (e) lack of communication among Naval activities working with wire rope; (f) carpenter stoppers in use currently do serious damage to wire rope at high loads - recommends modifications to existing designs and proper use of stoppers; (g) much of the experimental work which has been done of questionable value due to uncontrolled variations in test parameters.

Damage to wire rope is due to operation with associated equipment is greatest when rope operates over sheaves of too small a diameter; several examples of broken wires in ropes. Problems cited in elevator ropes which had varying load-elogation relationships because different vendors supplied the ropes. Impact loads and abrasion responsible for short lives of aircraft arresting gear.

Design specifications do not consider adequately bending stresses nor dynamic loads. Braided nylon rope considered a preferred substitute for wire rope for mooring, cargo handling, towing and messenger lines. Foreign made wire rope is considered to create problems for ultimate user due to non-uniform preform, workmanship, and diameter. Suggested that terminology in the general specs be changed from the archaic mild-plow, improved-plow, high-grade plow-steel, etc, to the ASTM, ASM or MIL Spec material designation. Recommended are control of manufacturing techniques, where performance of the end product is affected, e.g., source of the material, the wire drawing techniques, stranding and closing techniques. Recommends the development of a consolidated design document to provide design engineers with proper and adequate information on wire rope selection and the design of associated equipment. Recommends initiation of wire rope research and test programs to determine (1) optimum construction of wire rope for a

given application; (2) whether ropes with fiber core or independent wire rope core have best endurance for underway replenishment. Also the chemical composition of the actual wires should be indentified and properly specified. Stranding and closing techniques which produce rope with best fatigue life should be specified.

Investigations should be conduted to determine the bending-fatigue performance of electrolytic zinc coating compared to that of hot-dip galvanized.

The above should involve basic considerations involving use of aluminum coated wire rope in Naval application (ALVIN utilized aluminum coated wire rope).

83. Dollins, C.W., and Betzer, C.E., "Creep, fracture, and bending of lead and lead alloy cable sheathing," Univ. Ill. Engng. Exp. Sta. Bull. 440, pp., Nov. 1956.

84. Domes, V., "Design and Measurement of Drawing Die Profiles," Stahl and Eisen, Vol. 71, pp. 1147-1148 (1951).

85. Donandt, Hermann, "On the Durability of Cable and Cable-Wire," (in German), Arch. Eisenhuttenw. 21, 9/10, 283-292, Sept./Oct 1950.

Author discussess use of fatigue strengths in tension and in bending as based for selection of wire cables for specific applications. Analytic treatment is simplified by assuming that individual wires act independently. He compares results given by his method with standard German practice in applications to mine elevators, building evelators, cranes, and cable-suspended conveyers. A qualitative discussion of additional stresses resulting from twisted construction of actual cables is given. He concludes that practice of basing design upon ratio of maximum stress to ultimate strength of the material is more misleading for cables than for other machine parts.

AMR #1971 (1951)

86. Dong, R.G., and Steidel, R.F., Jr., "Contact stress in stranded cable," Exptl. Mech. 5, 5, 142-147, May 1965.

An experimental study of interstrand contact stresses existing in a stranded cable while it rests in its supporting clamp has been made using the stress-freezing photoelastic technique. Comparing the results with the Hertz contact-stress theory made it possible to establish criterion for suspension-clamp design.

AMR #3960 (1965)

87. Dorodynkh, B.N.,"A method of calculation for the parameters of the setting of deforming device when making doubly wound cables (in Russian)," Izv. Vyssh. Uchebn. Zavedenii: Gorn. Zh. no. 9, 105-114, 1959; Ref. Zh. Mekh. no. 10, 1960, Rev. 13894.

The stress analysis carried out by the author demonstrated that the magnitude of the residual stresses is less than the stresses produced in the wires when cables are being made by the usual technological process. This fact is used by him to explain the increase in the life of deformed cables.

AMR #7034 (1962)

88. Dorodnykh, B.N.,"On the determination of stresses produced in the fashioned wires when manufacturing cables of closed construction (in Russian)," Izv. Vyssh. Uchebn. Zavedenii: Gorn. Zh. no. 8, 118-124, 1959; Ref. Zh. Mekh. no. 4, 1961, Rev. 4V 439.

Formulas are given for the determination of stresses due to flexure and torsion in the elasto-plastic region produced in the fashioned wires during the making of cables. It was shown that in order to raise the service life of cables of closed construction it is essential to reduce the twisting stresses by the choice of suitable dimensions for the profile by decreasing the angle of twist of the wires in the cable and by making use of the method of predeforming the wires both in fashioned and in round sections.

AMR #2027 (1963)

89. Doyle, J.E., "Wire Under Tension and Transverse Forces", Philosophical Magazine, 1937 (vii), vol. 23, No. 158 pp. 1114-1128.

90. Drucker, D.S. and H. Tachau, "A New Design Criterion for Wire Rope," J. App. Mech., Trans, ASME 12, (1945).

Proposes a dimensionless bearing pressure as the proper parameter for choice of wire rope. The significance of this parameter is evident in plots of cycles to failure vs the bearing pressure ratio which shows a well defined curve for several ropes of 6 X 19 and 6 X 37 construction. The scatter is considered less than might be expected using the usual test parameters.

91. Drucker, D.C. and H. Tachau, "A New Design Criterion for Wire Rope" Journal of Applied Mechanics, March 1945, pp. A-33 - A-37.

This paer shows that a dimensionless bearing-pressure parameter B = 2T/U.d.D. (where T: Tension in wire rope, U: ultimate tensile strength, d: diameter of wire rope and D: pitch diameter of sheave) is of prime importance in the proper choice of wire rope.

92. Dull, R.G., "Rope Wire for Today's Applications," Wire and Wire Products, 41, pp. 1642-1643 (Octiber 1966).

93. Dunsby, J.A., and Thurston, F.R.,"A note on the effect of very infrequent load range changes on cumulative fatigue damage," Nat. Res. Counc. Canada, Aero. Rep. LR-331, 10 pp. + figs., Feb. 1962.

It has been confirmed experimentally that the infrequent interpolation of a changed load range on a basic fatigue loading can result in large changes in endurance which are not predicted by existing theories of cumulative damage. Several of the parameters involved have been investigated and a new hypothesis is proposed which under certain circumstances enables these changes in endurance to be estimated from basic fatigue data. The results have obvious relevance to the very significant effect of landing loads on the fatigue endurance of aircraft structures.

AMR #5847 (1962)

94. Eles, E.G., and Thurston, R.C.A.,"Fatigue properties of materials," Ocean Engineering 1, 2, 159-187 (Dec, 1968).

Paper is a general, compressed discussion of standard metallurgical and engineering aspects of fatigue concentrating on crack initiation and propagation work. A special section is devoted to environmental effects, followed by a consideration of fatigue properties of materials of likely use in marine applications, e.g, submersible vessels, offshore platforms, marine shafting and wire rope. Materials treated are ultra-high strength steels, aluminum alloys, titanium alloys and composite materials. Reviewer thinks too much space is devoted to established background. Section on reinforced plastics could have been expanded to give more quantitative detail especially comparing reinforced plastics with aluminum alloys in the notched condition. Significant omission is carbon fiber reinforced plastics which may be the source of abrupt technical breakthrough which authors consider unlikely.

AMR #1088 (Feb 1970)

95. Egawat., and Taneda, M.,"External pressure produced by multilayers of rope wound about a hoisting drum," 133-138, June 1958. (Bull. JSME 1, 2).

Relationship between the pressure of a wire rope wound on a hoisting drum and the number of layers wound on the drum is derived. Numerical results are plotted for typical combination of parameters. Experimental results from resistance strain-gageings on a model hoisting gear, check well with authors' theory.

AMR #267 (1960)

96. Elgerd, O.I.,"Transient suspension forces cuased by broken transmission line conductors," J. Franklin Inst. 275, 3, 227-245, Mar. 1963.

A method is presented by means of which transient suspension forces caused by broken transmission line conductors may be predicted. These forces could be computed from a system of partial differential equations but because of the complexity involved no attempt has ever been made. Data have instead been obtained from full-scale field tests. It is demonstrated that the problem is amenable to prediction by means of analog computer. In addition, the technique is applicable to the important case where the line is subject to hurricane wind forces, a case which clearly cannot be studied experimentally.

97. Elsworth, W.M., "General Design Criteria for Cable Towed Body Systems using Faired and Unfaired Cable," CPI (Cleveland Pneumatic Industries), (October 1960-TN-6634-1.

98. Elton, M.B., "Radiographic Field Tests Reveal Vibration Fatigue Breaks in High-Voltage Power Conductors," presented at Society for Nondestructive Testing, Los Angeles, Calif., March 23, 1961.

99. Elton, M.B. and A.R. Batiste, "Vibration-Fatigue Breaks Revealed by Instant X-Ray," Elec. Light and Power, Vol. 43, pp. 44-46, Sept. 1965.

100. Engel, E.," Bending stresses of a rope on an elastically lined roller (in German)," Ost. Ing.-Arch. 11, 3, 238-243, Nov. 1957.

An approximate method is presented for the determination of the load distribution (assumed to be parabolic) between a rope and an elastically lined roller. The numerical results are sufficiently accurate for practical purposes in view of the uncertainties and idealization inherent in a more rigorous analysis. As a justification, two numerical examples are presented and compared with an exact theory due to Czitary. Agreement is satisfactory for practical purposes.

AMR #1123 (1960)

101. Engel, E.," Calculation of rope pulleys with the aid of matrices (in German)," Stahlbau 31, 4, 97-102, Apr. 1962.

This paper considers a spoked pulley, either driven or not driven by a rope. By the use of matrix algebra, the author is able to give a concise and elegant analysis. A standard sector containing one spoke

is first considered, and the moments, forces, and deformations at the two ends of the sector are related through a matrix equation. This equation is applied recursively around the entire wheel, resulting in six linear equations whose solution yields the solution for the entire wheel. A conclusion of the analysis is that deformations cannot be neglected in the determination of stresses.

AMR #925 (1963)

102. Engel, E., "The torsional tendency and torsional stiffness of cables, (in German)," Ost. Ing. Z. 1, 1, 33-39, Jan. 1958.

Mathematical treatment of torsional phenomena in cables used for cranes and rope-railways. Various types are analyzed with respect to the way the cable is made of the composing wires. Making several simplifying suppositions author derives formulas for a first-order theory, giving a linear relation between the torsional moment and the tension. A numerical example is added.

AMR #1885 (1959)

103. Engel, E., "Twisting of wire ropes and their torsional rigidity (in German)," Ost. Ingenieur Z. 1, 1, 33-39, Jan. 1958.

The twisting effect of a tension force on wire ropes is discussed. Relations are derived between the tension force and the induced twisting moment and between the moment and the angle of twist. The torsional rigidity of the wire rope is then given by the ratio between the moment and the angle, as usual.

AMR #71 (1959)

104. Evaluation of Wire Rope, "Evaluate, Test, and Manufacture an Improved Wire Rope and Cable," Metals and Controls, Inc., Attleboro, Mass., Qtly Report No. 6, Contract No. S-922232 (Dec 31, 1966). Available: DDC as AD 807 266L.

105. Fatigue Research on Steel Wire, (Engineering, 1935, vol. 139, June 7, pp. 603-604). An editorial summarizing recent research on fatigue of steel wire.

106. "Fatigue Testing of Wire", Aircraft Engineering, 1934, Vol. 6, pp. 251-253: Engineer, 1934, Vol. 158, Aug. 17, pp. 167-168: Engineering, 1934, Vol. 138, Aug. 10, pp. 139-140: Wire and Wire Products, 1935, Vol. 10, July, pp. 2[illegible] 274, 284-285.

107. Fayoux, P., "Equilibrium of a cable under generalized forces (in French)," Ann. Ponts Chauss. 125, 3, 270-282, May- June 1955.

Blondel's solution for a loaded cable is extended to include the effects of arbitrary loading and temperature variation with a non-homogeneous cable material.

AMR #696 (March 1956)

108. Foppl, H., "The evaluation of macroscopic residual stresses in cylindrical bars," J. Iron Steel Inst. Lond. 168, part 1, 15-22, May 1951.

Paper deals particularly with residual stresses produced in plastic deformation of surfaces by shot-peening or surface-rolling. Author measures residual stresses in shot-peening or surface-rolling. Author measures residual stresses in shot-peened bars destroying, by etching away, the plastical deformed part (cylindric surface), until only the elastic part (core) is retained. Length changes vs. removed thickness rises first linearly, passes a maximum point, and gradually approaches the horizontal. Author's new experiments are more accurate than previous ones [Mitt. Wohler-Inst., 112, 557, 1949, Braunschweig.]. Considering some recent experiments in the straining of metals, and "intermediate layer" is introduced, a discontinuity between the biaxial plastically stressed surface and the triaxial elastically stessed core in which a "stress reversal" in the plastic deformation takes place. Residual stresses are calculated from strains in principal axes and Hooke's law introducing strain ratios for surface and core, $\delta_s = e_{ts}$ and $\delta_k = e_{rk}/e_{ak}$. Calculation is possible even if the strains are measured in only one direction. Author's equation reduces to Heyn-Sachs if Poisson's ratio is 0 (both strain ratios are zero, too). Calculated core stresses are much greater in axial than in radial direction, implying negative radial or tangential strain, i.e., $\delta_k < 0$. In the surface $\delta_s > 0$. Author assumes both δ constant (error 10%, better than with $v = 0$). The assumed δ are altered so that both conditions of equilibrium are fulfilled. Sachs' formula only fulfills one, giving inaccurate values for tangential and radial stresses. As it does not consider the stresses in the third axis, Sachs' formula is only valid for ring-shaped cross section in which the radial stress can be neglected. Author says [illegible] the removal of cylindrical layers instead of boring them out. Future research will show if it is preferable to replace Sachs' formula by a more complicated calculation or to measure directly the stresses in the core by other experimental techniques. The calculated values show the plausibility of assuming a biaxial state in the surface and a stress reversal at 0.013 in depth. A very fine and interesting paper.

AMR #4097 (Nov 1951)

109. Francis, A.J., "Analysis of suspension cable behaviour," Engineer 219, 5709, 1094-1101, June 1965.

Approximate equations are derived for deflections of cables with concentrated loads. Two sets are derived, one in which the loads are small compared to the cable weight and the other in which the loads are large. Load-deflection curves from the two sets of equations are compared to a numerical solution in which neither approximation is made. The numerical curve fits smoothly in the approximate curves at the small and large load extremes, with only a small intermediate range of loads where the approximate expressions differ slightly from the numerical solution. The paper is lengthy and the approximate expressions are not conveniently summarized, so that the reader must invest a great deal of time to use the results.

AMR #6631 (1965)

110. Francis, A.J., "Single cables subjected to loads," Civil Engng. Trans. CE 7, 2, 173-180, Oct. 1965.

A simple approximate procedure is presented for the determination of two types of cable property; (1) the over-all flexibility of a cable carrying any given system of loads when the distance between the ends is altered; (2) the deflections of such a cable when further loads are added. The method is based on a simple basic equation and leads to a single formula covering the complete range of values of the ratio - applied loads/weight of cable. The errors involved in problems of type (1) are small even when the ratio of sag to span is large and the cable is steeply inclined to general direction of the applied loads which need not be parallel. For problems of type (2), the method is accurate only for parallel loads.

AMR #3477 (1966)

111. Francis, E.L., "Studies of the Wire Drawing Process. VII.-- The Application of Metallic Coatings as Lubricants, with Special Reference to the Drawing Properties of a Lead Coated Austentitic Chromium Nickel Steel." Iron and Steel Inst., Carnegie Scholarship Memoirs, 1934, 23, pp. 47-63.

112. Franke, E.A., "Testing of Wire Rope for Load Lifting Service," DRAHT, Vol. 13, No. 3, Mar 1962, pp. 114-116.

Describes a test installation for determination of resistance to repeat impact tensile stress alone and in combination with other types of stress. The impact stress at the start of the lift operation is considered the main reason for ropes failure.

113. Friction on Cables, Avoiding friction on curved prestressing cables, Concr. Constr. Engng. 52, 3, 109-112, Mar. 1957.

AMR #3994 (1957)

114. Friedman, Edward, "A Tensile Failure Mechanism for Whisker Reinforced Composites," 22nd Annual Meeting of the Reinforced Plastics Division (Shoreham Hotel, Washington, D.C.).

An analytical model of tensile failure of uniaxially oriented discontinuous fiber reinforced composites is developed for loading in the fiber direction. The model simulates the failure mechanism resulting from an accumulation of fiber fractures. Statistical distribution functions characterizing fiber strength and geometry are employed in order that the model may be utilized in the study of tensile failure of whisker reinforced composites. Specific forms of the distribution functions are used to obtain quantitative results regarding the effects of the properties of the constituent materials on composite strength. Tensile tests performed on single-layer glass and boron composite specimens indicate that the strength of a discontinuous fiber composite can approach that of the corresponding continuous fiber composite, as predicted by the analytical model. An example is presented which applies the model to failure of alumina whisker-epoxy resin composites, making use of the available data on whisker properties.

115. Frieling, G.H., "C-Clad: A New Corrosion - Resistant High-Strength Ocean Cable Material," Wire and Wire Products, Vol. 40, 228-231, February 1965.

116. Fulweiler, W.H., "Inspection and Some Tests of Some Worn Wire Ropes," Journal of Research, Bureau of Standards, July - Dec., 1936, Vol. 17 pg 401.

Evaluated 229 specimens obtained from 79 worn wire ropes. Actual and estimated strengths based on Roebling Co. charts were found to be in close agreement.

117. Gabrielli, G., Antona, E., and Massa, P.," Experimental determination of the modulus of elasticity of cables for aeronautical use (in Italian)," Atti della Accademia delle Scienze di Torino 100, 5a, 781-795 (1965/55).

Paper presents test results of elongation of steel cables under load, which may be useful to designers. The problem probably warrants fundamental investigation by taking measurements of all deformations of the cables and wires.

AMR #7039 (1967)

118. Gambreel, Jr., S.C. and Case, R.O., "New Machine for Accelerated Fatigue Tests of Wire Rope," Wire and Wire Products, Vol. 43, 46-9 (June 1968).

119. Gatts, R.R.," Application of a cumulative damage concept to fatigue, ASME Trans, 83 D (J. Basic Engng.) 4, 529-50. Dec 1961.

Author proposes a hypothesis for damage based on the following assumptions: (1) The instantaneous endurance limit S_e decreases during repeated loading with the stress amplitude S, if $S > S_e$, corresponding to a damage function that represents in some way the quantity of recoverable stored strain energy per cycle: $dS_e/dn = - k(S-S_e)^2$. (2) The instantaneous static strength S_f decreases proportionally with the endurance limit, $S_e = CS_f$, until the stress amplitude is reached, $S_f = S$, and failure occurs. This assumption is somewhat weak and not in good agreement with test results. An equation is obtained for the S-N diagram with constant stress amplitude S_{e0} for infinite life: $kN = 1/(S-S_{e0}) - 1/($[illegible]$)$. This corresponds to the common empirical equation $N(S-S_{e0}) =$ constant with an additional member that improves the curve for higher values of S.

In the second part of the paper nondimensional parameters are used with good result to set up a composite plot of S-N data for normal rotating bending tests of various steels. With the same parameters a general concept of cumulative damage is given and compared with other theories.

120. Gibbons, T. and C.O. Walton, "Evaluation of Two Methods for Predicting Tow line Tensions and Configurations of a Towed Body System using Bare Cable" David Taylor Model Basin, Report 2313, December 1966.

Two alternative methods for predicting steady-state configurations and towline tensions are evaluated by comparing predicted data with experimental data. Between the two methods, Method 1 is shown to provide better overall predictions of cable tension, cable angle at towing ship, and body depth for the bare-cable case. The best agreement between the experimental data and the data predicted by Method 1 is obtained with a cable drag coefficient of 1.5 and a tangential force factor of 0.02. Method 1 is the one described in DTMB Report 687 "Tables for Computing the Equilibrium Configuration of a Flexible Cable in a Uniform Stream" by L. Pode. Method 2 is due to L.F. Whicker "The Oscillatory Motion of Cable-Towed Bodies" University of California, Series 82, May 1957. The two methods are essentially the same but differ in the loading functions which are used.

121. Gibbons, T. and C.O. Walton, "Evaluation of Two Methods for Predicting Towline Tensions and Configuration of a Towed Body System using Bare Cable," DTMB Report 2313, 1966.

122. Gibson, P.T., et. al., "Analytical and Experimental Investigation of Aircraft Arresting-gear Purchase Cable," under Contract N-156-47939 for Naval Air Eng. Center, July 3, 1967.

123. Gibson, P.T., G.H. Alexander and H.A. Cress, "Validation of Design Theory for Aircraft Arresting-Gear Cable," prepared under Contract NOW 65-0503-C for Nav. Air Systems Command, Jan. 19, 1968.

124. Gibson, P.T. and H.A. Cress, "Analytical Study of Aircraft Arresting Gear Cable Design," under Contract NOW-64-0461-f for USN Nav Weps, May 28, 1965.

125. Gibson, P.T. and Cress, H.A., "Torsional Properties of Wire Rope," ASME Paper 69-DE-34, New York, Jan. 30, 1969

For a wire rope to be used to the fullest advantage, its operating characteristics must be understood by the design engineer. One characteristic which is often troublesome is the torque that is developed when a wire rope is under a tensile load.

Discussed are the techniques used to accurately calculate the torsional properties of almost any common wire-rope construction. A simplified analysis is developed for wire ropes composed of single-operation strands which alows the calculation of torque knowing only the rope diameter, rope lay, and strand lay.

Experimental data presented for 18X7 nonrotating wire rope reveal the influence of rotation on the developed torque and on the breaking strength of this construction.

126. Gill, E.T. and Goodacre, R., "Some Aspects of the Fatigue Properties of Patented Steel Wire", Journal of the Iron and steel Inst., 1934, No. II, pp. 293-323.

Indicates that properties of wire in bending fatigue, i.e., the fatigue limit, are chiefly the properties of the surface. For higher percentage reductions, the effect of C content is completely obscured by the effect of the decarburized surface. Felt that the fatigue limit of non-decarburized wire higher than decarburized wire, felt that the endurance limit was less.

127. Gill, E.T. and Goodacre, "Some Aspects of the Fatigue Properties of Patented Steel Wires. Part III. Note on the Effect of Low-Temperature Heat Treatment on Decarburized Wires," Iron and Steel Institute, Carnegie Scholarship Memoirs, 1936. Vol. 25, pp. 93-100.

The findings made in an investigation of the effect of low-temperature heat-treatment on the fatigue properties of [illegible] free from

decarburization have already been published in an earlier paper in this series, and it was considered that it would be advisable to carry out a similar investigation upon decarburized material. The same steels were used as before - containing 0.37, 0.55, 0.79 and 0.86 per cent of carbon, respectively - drawn with varying reductions between 34.5 and 90 per cent. and tempered at 150°, 200°, 300°, and 400°C. The criterion of the occurrence of decarburization was the presence of an envelope of free ferrite in the rod visible at a magnification of 100; the visible depth on the finished wire was found to vary between 0.0005 and 0.002 in. The results show that, although the general mechanical properties suggest a similiar trend for both conditions of surface, the fatigue properties of the decarburized wire after low-temperature heat-treatment are very different from those of the corresponding material free from decarburization. The fatigue limits become erratic, especially for the higher carbon contents. There ppears to be an optimum carbon content giving the best fatigue-resisting properties; an increase above this value actually gives lower limiting-fatigue-stress values after heat-treatment. As the carbon content increases, the tempering temperature to obtain the best fatigue-resisting properties must be raised. The limiting fatigue stresses obtained for decarburized wire after tempering are very much lower than those found for the corresponding material drawn free from decarburization, the differences for the best recorded figures for each condition of surface being 6.9, 6.6, 10.2, and 17.9 tons per sq. in. for the 0.37, 0.55, 0.79, and 0.86 per cent. carbon steels respectively. No attempt was made to find possible explanations for the results obtained, but it is thought that they are due to the conditions of internal stress which exist between the true structure of the material and the decarburized skin.

128. Gilmore, William, J., "Corrosion Resistant Wire Rope," U.S. Patent No. 3, 307, 343 (May 27, 1965).

129. Glushko, M.F., "Mechanical testing of wire ropes," Industr. Lab. 28, 8, 1038-1041, Feb. 1963. (Translation of Zavod. Lab., SSSR 28, 8, 981-983, Aug. 1962 by Instrument Society of American, Pittsburgh 19, Pa.).

An analysis and experimental results are given for the deformation of steel wire ropes under an axial load and a twisting mement, in the cases of pure tension, free tension, pure twisting and free twisting.

AMR #2128 (1964)

130. Glushko, M.F., "Nonsymmetric extension and the spin phenomenon in steel cables (in Russian)," Prikl. Mekh. 1, 5, 72-78, 1965.

An asymmetric extension of a single-layer steel cable is considered

which leads to a non-zero resultant mement in the cross sections. This moment seems to revolve about the axis of the cable with a changing position of the cross sections and produces a spiral bending (cork-screw form) of the cable.

It is shown that the spin phenomenon helps natural self-equilibration of tensions in the wires of the cable if some of the wires work defectively.

AMR #6185 (1966)

131. Godfrey, H.J., "The Fatigue and Bending Properties of Cold Drawn Steel Wire", Transactions of the American Society for Metals, 1941, Vol. 29, pp. 133-168.

Concluded: (1) fatigue influenced by carbon content; (2) cold working increases fatigue limit in proportion as the tensile strength; (3) polishing of the wire surface improves fatigue properties (4) decarburization of the surface causes a deterioration in properties in fatigue. In addition, effects given for: galvanizing and cold work (in bending fatigue).

132. Godfrey, H., "The Physical Properties of High Carbon Steel Rope Wire as Affected by Variations in Patenting," Wire and Wire Products, 1944, Vol. 19, Oct., pp. 635-642.

An investigation of the effect of patenting in lead at 900°, 1,000°, and 1,100°F on the tensile properties of wire for wire ropes is reported. Three steels containing 0.75 - 0.80 per cent of carbon were used; these were hot-rolled to 0.187 in. in dia., patented, and drawn to 0.083, 0.083, and 0.906 in. respectively, for final patenting. In the tensile test the reductions in area were approximately the same after patenting at 1,000° and 1,100°F, and were higher ater patenting at 900°F. The tensile strengths were approximately the same after patenting at 900° and 1,000°F, and were reduced by patenting at 1,100°F.

133. Godfrey, H.J., "The Physical Properties of Steel Wire as Affected by Variations in the Drawing Operations," Proceedings of the ASTM, 1942, Vol. 42, pp. 513-526; Wire and Wire Products, 1942, Vol. 17, Dec., pp. 704-710.

The Physical Properties of Steel Wire as Affected by Variations in the Drawing Operations. H.J. Godfrey. (Proceedings of the American Society for Testing Materials. 1942, Vol. 17, Dec., pp. 704-710). The author describes an investigation of the properties of an 0.7 per cent carbon steel wire drawn to 0.218 in., patented, and then drawn with 40 per cent, 30 per cent, 20 per cent reductions.

134. Goldstein, A., and Brereton, C.F.,"Some notes on the fatigue resistance of corroded prestressing wire,"Struct. Engr. 39, 10, 332-339, Oct. 1961.

Some data are presented on decrease in fatigue strength of cold-drawn steel wire (for use in prestressed concrete) due to pitting corrosion by salt spray. Excessive pitting produced as much as 60 per cent decrease in 10^7 cycle fatigue strength.

AMR #4623 (1962)

135. Goodacre, R., "Some Aspects of the Fatigue Properties of Patented Steel Wires, Part IV. A Study of the Endurance Properties at High Stresses," Iron and Steel Institute, Carnegie Scholarship Memoirs, 1936, Vol. 25, pp. 111-139.

Under certain conditons of service, cold-drawn wire may be subjected to alternating stresses, the magnitude of which is considerabley in excess of the limiting fatigue stress for the material, and consequently some knowledge of its behaviour under such conditions is very desirable. Attention was given to this aspect of the fatigue properties of wire is the first paper of this series, and in the work described in the present memoir a study was made of the effect of alternating stresses of high magnitude upon cold-drawn wires. The materials investigated cover a range of steels, the carbon contents of which varied between 0.36 and 0.86 per cent drawn from both lead- and air-patented rods. The amounts of drawing varied between 25 and 90 per cent reduction, and paralled tests were carried out on normal decarburized material and on wire which had been drawn free from decarburization. All wires were tested at 0.080-in. dia., and the ranges of stress were so chosen that facture occurred after approximately 20,000 - 100,000 repetitions of stress had been applied, the Haigh-Robertson machine being used. Tensile and bend tests were also recorded for each wire. From the results obtained it is concluded that whilst at very high stresses decarburized wire has the superior endurance, in the ranges which are likely to be met in service wire free from decarburization is superior.

136. Goodacre, R., "The Effects of Heavy Oils and Greses on the Fatigue Strength of Steel Wire," Engineering, 1935, Vol. 139, May 3, pp. 457-458; Wire and Wire Products 1935, Vol. 10, Oct., pp. 473-475.

An account is given of experiments conducted in order to ascertain the effect of heavy lubricants on the fatigue strength of steel wire having a carbon content of 0.55 per cent and a limiting fatigue range (in air) of 23.7 tons per sq. in. It was discovered that the fatigue strength improved with increasing viscosity of the oils up

to a certain limit, when there was a marked fall. The author suggests that the improvement in fatigue strength cannot be solely attributed to the exclusion of air (and hence diminution of corrosion fatigue), and considers that the oils may have the effect of filling up the surface blemishes on the wire itself, thus delaying failure. It was also noticed that the oils improved the endurance at stresses above the fatigue limit.

137. Gormally, J.M. and Pringle, R., "The Analysis of Mooring Systems and Rigid Body Dynamics for Suspended Structures," Bell Telephone Laboratories, Inc., Whippany, N.J., Tech Report 14, Contract N00014-66-C-0005 (December 30, 1966). Available: DDC as AD 666-615.

138. Gough, H.J. and Sopwith D.G., "The Influence of the Mean Stress of the Cycle on the Resistance of Metals to Corrosion-Fatigue, Journal of the Iron and Steel Institute, 1937, No. I, pp. 293p-313p; Discussion, 340p-351p.

Whilst much attention has been devoted to the resistance of materials to corrosion fatigue under cycles of reversed stress, no work has hitherto been carried out on the equally important practical cases of repeated or fluctuating stresses. This paper describes the results of tests under these conditions made on six aircraft materials, the behaviour of which under reversed stresses has previously been reported. These comprised a cold-drawn 015 per cent carbon steel, three stainless steels, duralumin, and a magnesium alloy containing 2 1/2 per cent of aluminium. These were tested in air, also in a spray of 3 percent salt soultion, under cycles of repeated and of fluctuating stresses.

The results show that, as in air, the fatigue resistance of a matherial in a corrosive envirronment is considerabley influenced by the mean stress of the applied cycle. As in the case of reversed stresses, no corrosion-fatigue limit was indicated for any of the materials. If the range for any given endurance is plotted against the mean stress, the form of the curve obtained is in general similar to the obtained in air, using the fatigue limit in place of the endurance range.

139. Groover, R.E.; "Analysis of the Failure of the AUTEC TOTO II Deep Sea Moor and the Performance of its Cathodic Protection System," NRL Memordandum Report 1950, November 1968.

Contains background information on design and installation of a wire rope three-point deep sea moor coated with bituminous substance and protected cathodically at the critical areas. Describes the failure of the moor after 4 1/2 years and presents results of the study of the corrosion pattern. Examination showed that where the cable was adequately cathodically protected, the lack of a coating did not re-

sult in severe corrosion. Recommended that better bituminous coatings be developed and that cathodic protection be designed into the system as a secondary defense against corrosion. Also recommended that impressed current systems be considered where adequate power is available.

140. Gursoy, A.H., "Lateral wind on side spans of suspension bridges," Journal of the Structural Division, Proceeding os the American Society of Civil Engineers 94, ST10, 2399-2410 (Oct. 1968).

The deflection of a uniform, simply-supported truss suspended from a pair of tower-to-anchorage cables is obtained as a Fourier series, the coefficients being derived from virtual work via a general equation for a_n, which allows n terms to be found from n linear equations. Three dimensional parameters, α, β, γ, govern this deflection (and the shearing forces and bending moments obtained from it). With 0.9 of the total wind loading assumed to be carried by the truss, coefficients for the central deflection, mements at mid- and quarter-spans, and the tower reaction at truss level are plotted against the parameters in sight diagrams. A numerical example is given; also, the general equation for a_n is derived in an appendix.

The paper is intended as a design aid (the problem has been fully computerized elsewhere). The design charts provided would serve mainly as a guide (they are given only for two specific values of α and of β). Calculations from the general equations for a_n would probably be required but should not be to difficult or tedious.

AMR #6178 (Aug 1969)

141. Guyonnet, M. Chevalerias, G., and Derue, P., "Computer solution of moorings with several fixed points (in French)," Bulletin de l' Association Technique Maritime et Aeronautique no. 65, 401-423 (1965).

The fastening of big ships in harbors is done by mooring systems with many fixed points. Paper presents the fundamental geometric relations of such systems having many structural components. The numerical method for the structural analysis of such complicated systems then is shown. Since several parameters of the equations have to be estimated initially, the solution can be found only by an iterative procedure. This procedure can be repeated easily by using an automatic program. Authors show flow diagrams for several types of mooring systems in full detail.

AMR #9772 (1967)

142. Hagarman, Paul and Kressley, Lin, "Evaluate, Test and Manufacture an Improved Wire Rope and Cable," Texas Instruments, Inc., Dallas, Texas, Final Report (July 31, 1967). Available: DDC as AD 819-202L.

143. Handbook of Ocean and Underwater Engineering, Edited by John J. Myers, Carl H. Holm, and R.F. McAllister, McGraw-Hill Book Co., San Francisco (1969), "Rigging, Tackle, and Techniques: Rigging Materials and Techniques," (C.H. Holm), pp. 4-75 to 4-90 and 4-125.

144. Hartbower, C.E., Gerberich, W.W., and Liebowitz, H., "Investigation of Crack Growth Stress-Wave Relationships," Int. J. Eng. Fract. Mechanics 1, 291-308 (1968).

145. Hartbower, C.E., Gerberich, W.W., and Reuter, W.G., "Theoretical Model of Ductile Fracture Instability Based on Stress - Wave Emission," Final Report from Aerojet General Corp. to ONR, Feb. 1969.

146. Hartbower, C.E., Gerberich, W.W., Reuter, W.G and Crimmins, P.P., "Stress-Wave Characteristics of Fracture Instability in Constructional Alloys," Rep. from Aerojet General Corp. Prepared for ONR, July 1968.

147. Hearle, J.W S.," On the theory of the mechanics of twisted yarns," Journal of the Textile Institute 60, 3, 95-101 (Mar. 1969).

The theory of the extension of continuous-filament yarns is re-examined and simplified by means of energy methods and is stated in essestially four equations which can be used for numerical computation. The limitations and possible generalizations of the theory are discussed.

AMR #904 (Feb. 1970)

148. Heilig, R.," Statics of heavy ropes (in German)," Stahlbau 23, 11, 253-258, Nov. 1954; 12, 283-291, Dec. 1954.

AMR #2822 (1956)

149. Heilig, R.," Theory of heavy unelastic ropes (in German)," Stahlbau 24, 6, 133 [illegible], June 1955.

[illegible] f approximation is presented which takes into account the [illegible] exerted upon the balance of moments at the nonelongated r[illegible] by the horizontal displacements as measured from the c[illegible] of the weightless rope which is exclusively loaded by use-f[illegible]). This method permits the horizontal pull to be determined w[illegible]at accuracy, whereas the rope curve is not obtained, the latter b[illegible] calculated with the aid of another method of approximation.

AMR #414 (1956)

150. Heilmann, W., "Fatigue Tests on Wires and Wire Ropes," Wissenschaftliche Abhandlungen der deutschen Material preufungsanstalten, No. 3, 1939, pp. 27-30.

151. Heller, R.A., and Donat, R.C., "Random-load fatigue tests on a fail-safe structural model," Experimental Mechanics 7, 10, 409-418 (Oct. 1967).

Paper presents results of investigation of fatigue life and "fail-safe" capacity of multimember redundant model structures. Authors' previously-plublished theoretical approach, briefly reviewed, presents equations based on assumption that both strength of material and applied load can be described by exponential probability-distribution functions. Ten-member redundant structural models of 2024-T4 aluminum alloy were subjected to cyclic cantilever bending loads of constant amplitude and programmed "randomized" variable amplitude. Predicted and observed values of fatigue life to first failure agreed closely. However, existence of "fail-safe" condition after failure of weakest member was demonstrated consistently in tests, but not predicted by theory. Further work is in progress.

AMR #1011 (Feb 1969)

152. Hempel, M., "Fatigue Testing of Steel Wires," Draht, German ed., 1955, 6, April., pp. 119-129; May, pp. 178-183.

Discussion of: testing machines; steels used in rope, spring, and reinforced concrete wire; endurance curves of patented steel wires; effect of method of manufacture, heat-treatment, size, composition, surface condition, surface coatings - on the fatigue properties of wires.

153. Horton, J.L. and R.A. Yagle, "Analysis of Assumed Mooring Arrangement for Maritime Class Ship" Marine Technology, pp. 257-266; July 1968

This paper deals with an analysis of wind conditions which would be sufficient to establish the sequence necessary to cause parting of one line, followed by parting of second and third lines and, finally, by full failure of the mooring arrangement. Wind-tunnel tests on a model of the ship are reviewed.

154. Hetenyi, M.I., Handbook of Experimental Stress Analysis, Wiley, 1950

155. Hill, R. and Tupper, S.J., "A New Theory of the Plastic Deformation in Wire Drawing," J. Iron and Steel Inst., Vol. 159 pp. 353-359 (1948).

156. Holl, J., "Theoretical and Practical Determination of the Best Shape of Wire Drawing Dies," Hutnik (Prague), Vol. 3, pp. 130 134 (1933).

157. Holmes, P., "Mechanics of Raising [illegible] Lowering Heavy Loads in the Deep Ocean: Cable and Payload Dynamics", U.S.N. Civil Eng. Lab., R-433, April 1966.

158. Hoover, Hubert M., "Wire [illegible]," Geomarine Technology, Vol. I (3), 32-22 (February 19[illegible])

159. Hor[illegible], J.L. and R.A. Yagle, "Analysis of Assumed Mooring Arrangement for Maritime Class Ships," Marine Technology, July 1968.

160. Howe, James [illegible], "Determinatin of Stresses in Wire Rope as Applied to Modern Enginee[illegible] Problems" Transactios of the ASME, Vol. 40, pp. 1043- 09[illegible] [illegible]18.

This paper deals with the derivation of formulae to compute direct and induced stresses developed in wire ropes by static or moving tension, bending, and horizontally suspended loads.

The values for the bending stresses produced in ropes that are passed over sheaves, as determined by the formula of Reuleaux, Rankine, Unwin and Hewitt are correct only for ropes composed of straight wires. Owing to the twisting of the wires in the formation of modern rope, the actual bending stress in it is much smaller than in a solid bar, and its true value, S, may be computed by replacing in the fundamental assumptions the modulus of elasticity of a solid bar, with E_R, the experimental value or the modulus of elasticity of the rope as a whole; thus the Reuleaux formula becomes

$$S = E_R (d/D)$$

where d is the diameter of the wire in the rope, and D the diameter of [illegible].

[illegible] author develops a method for determ[illegible] [illegible]sticity [illegible] both strands and rope in [illegible] where experi[illegible] are not available. [illegible] in regard to the customary practice followed in specifications, general remarks are offered on the required proportionality between the [illegible] [illegible]ameters and the size of the rope, the manner of classifying strengths in the manufacturer's rope catalog, and the special requirements in the [illegible]sical properties of the wire forming the rope

161. Blank

162. Howell, H. G., "The Friction of a Fibre Round a Cylinder and its Dependence upon Cylinder Radius," J. Text. Inst. Trans., 45, 8, T575-T579, Aug 1954.

AMR #1690 (1955)

163 Hu, L.W., "Analysis of die profiles in wire drawing," J. Franklin Inst. 263, 4, 317-330, Apr 1957.

Assuming total plastic deformation and considering strain-hardening, the draw stress, die pressure and complete stress distribution in a wire drawn through dies having straight, concave, convex or bell-shaped profiles are determined. Bell-shaped die is found to give the lowest draw stress and most uniformly distributed pressure and friction force between die and wire. This agrees with experimental evidence supplied by V. Domes [Stahl u. Eisen 71, 1147-1148, 1951].

AMR #3330 (1957)

164. Hubert, F.J., "Simplified sag-tension equations for power lines," Proc. Amer. Soc. Civ. Engrs. 88, PO 1 (J. Power Div.), 67-88 May 1962.

Paper presents a collection of empirical equations and approximative formulas to calculate spaceing (lay of cable) and state of tensions in suspended conductor cables of power lines, considering influence of deadweight, ice load and wind load, and taking into account influence of yield and creep on sag-tension relation. Author does not give any deduction or other details of these equations but the reader will find some indications about the percentage of error compared with exact solutions. The compound action between steel cable and aluminum or copper wires is considered, introducting a fictitious modulus of elasticity and an adequate tempera ure coefficient. While exact solutions of sag-tension problems are very laborious due to the intervention of basic catenaria for dead weight and parabola for wind load, author introduces only parabolas for the simultaneous action of gravity and wind forces using correction factors and, if necessary, adding terms of improvement.

The presented empirical formulas include the solution of nearly all problems connected with practical design of elevated power lines. Their use will save very much time in comparison with conventional methods but designer must carefully check results obtained and prove their sufficient exactitude.

AMR #1385 (1963)

165. Hudson, C.M., and Hardrath, H.F., "Effects of change of stress amplitude on the rate of fatigue-crack propagation in aluminum alloys," NASA TN D-1960, 22-p. Sept. 1961.

AMR #2080 (1962)

166. Hundy, B.B., and Singer, A. R. E., "Inhomogeneous deformation in rolling and wire-drawing," J. Inst. Metals 83, 7 pp., 1954-1955.

Microhardness measurements made on copper, 70:30 brass, aluminum, and mild steel indicate that there is an analogy between the inhomogeneity of deformation rolled strip and that in drawn wire. Copper, brass, and aluminum all show surfacehardening when lightly rolled or drawn. The inhomogeneity is dependent on the working conditions, and disappears after moderate reductions by rolling or drawing. The surface-hardening is caused by frictional forces acting between the rolls or die and the metal, and increases as the coefficient of friction increases. In general, a specific surface hardness can be associated with definite frictional conditions.

Rolling and drawing also give rise to a secondary zone of hardenging situated between the core and the surface of the metal. This can be observed in both copper and steel, and it does not decrease in magnitude as the reduction is increased. It is believed that secondary hardening is associated with the manner of deformation during rolling and drawing, and is largely independent of friction.

AMR #166 (1956)

167. Ikeda, S., and Ueno, I., "Equivalent bending and torsional rigidity of wire rope and stress induced in elementary wire of wire rope when it is bent along the sheave," Proc. 1st Japan nat. Congr. appl. Mech., 1951; Nat. Committee for Theor. appl. Mech., May 1952, 199-208.

The wire rope is composed of central and several side strands. Equivalent bending and torsional rigidity of each strand being determined, those of the wire rope are calculated. Authors then deduce the values of the stress in elementary wire of rope bent along the arc of a sheave, having obtained the bending stress in central wire, bending and torsional stress in side wire, and stresses induced in elementary wire of rope of central and side strands. Characteristic bending curve is drawn to show the stress induced in bent rope.

AMR #48 (1955)

168. Imai, M., and Nagano, S.,"Friction property of lining for Koepe winders," Bull. JSME 5, 18, 381-388, May 1962.

Considerable analysis and experiment are expended on a device which might be considered emprical in that the friction property is an operational-time- and temperature-dependent function. Neither parameter was considered. Data should be qualitatively useful to designers.

AMR #926 (1963)

169. Imre, G., and Takach, G.,"Calculation of anchored holding ropes of cableways (in Hungarian)," Melyepitestudomanyi Szemle 11, 2, 81-87, Feb 1961.

Authors deal with the calculation of anchored holding ropes of cableways. Effects of various load distributions and changes of temperature are taken into consideration.

AMR #108 (1962)

170. Isaacs, J.D., et. al. "Deep Sea Mooring," Bull. Scripps Inst. Ocean. Vol. 8 (3), 271-312, 1963.

171. Ishchlinskii, A. Yu.,"On an integrodifferential relation in the theory of elastic threads (ropes) of variable length (in Russian)," Ukrain. Mat. Zh. 5, 3, 370-374, 1953. (English translation by M.D. Friedman on file with Scientific Translations Division, Library of Congress).

Author obtains the differential equation for the time-dependent deformation of an end-loaded vibrating cable running over a pulley. Weight of cable is included.

AMR #37 (1955)

172. Jaumotte, A., Kiedzynski, A., and Strebelle, Jr.,"Machine for fatigue testing of a cable in tension (in French)," Rev. Tijdschr.-Mecan. Werk 6, 3, 137-144, 1960.

173. Johnson, A.A., Lewenstoin, T., and Inbembo, E.A.," The effects of the hydrostatic pressure in a deep ocean on the mechanical behavior metals," Ocean Engineering 1, 3, 201-232 (Feb. 1969).

The nucleation of a microcrack in a metal by dislocation coale-

scence is governed principally by shear stresses and is, therefore, to a first approximation, not influenced by the application of a hydrostatic pressure. Its propagation is, however, made more difficult by a hydrostatic pressure because it is governed principally by the tensile components of stress normal to the plane of the crack. As a result, a metal which is brittle at ambient pressure may become ductile when a hydrostatic pressure is applied, i.e., the ductile-brittle transition temperature may be lowered. A simple calculation shows that this decrease in transition temperature should be approximately proportional to the pressure and should be several tens of degrees for the magnitude of pressure found in a deep ocena. A limited number of experiments carried out in laboratory pressure chambers and reported in the literature show that this calcualtion is at least approximately correct.

AMR #1098 (1970)

174. Johnson, W.,' The cutting of round wire with knife-edge and flat-edge tools, Appl. Sci. Res. (A) 7, 1, 65-88, 1958.

Experiments are described on the indenting and cutting of round wires between 0.063-in. and 0.625-in. diam of copper, galvanized and straight drawn medium carbon steel, and a special steel with wedge-shaped tools, to investigate the basic mechanics of the operation Considerable use is made of some theoretically well-analyzed and analogous cases in the plane-strain cutting of strip, and experimental evidence of qualitative agreement is presented. The investigation was carried out to determine the effect of the greatest load required to sever matherial, of wedge tool angle, of flat on the end of the wedge, wire diameter and material properties; in particular the logarithm of the greatest cutting load is shown to be directly proportional to the logarithm of the wire diameter The paper concludes with observations on the physical action and consequences of cutting

AMR #4543 (1958)

175. Jones, M.H and Brown Jr., W.F., "Acoustic Detection of Crack Initiation in Sharply Notched Specimens," Mater Res. 4, 120-129, (1969).

176. Kachurin, V K.," Flexible ropes with small supporting points (in Russian)," Moscow, Gostekhizdat, 1956, 224 pp. 7r 40k; Ref Zh. Mekh. No. 6, 1959, Rev 6972

This is an investigation of filamets with small supporting points: single-span, multi-span, double-banded chains made up of stiff disks

and their combinations with the filaments. The equations for the curve of the suspension of the filament with a vertical load are expressed through the deflection moments in a simple beam of the same span, while the length of the filament is expressed through the transverse forces. Both vertical and horizontal loadings are considered. Some more precise calculations are examined in the form of taking into account elongations, consideration of the stiffness of the filament in deflection, and so forth. The book contains a large number of examples. A short survey is given of the existing literature.

AMR #5628 (1960)

177. Kakuzen, M., "Two-dimensional profile of drawing die and extruding nozzle by plasticity theory," Proc. 1st Jap nat. Congr. appl. Mech., 1951; Nat. Committee for Theor. appl. Mech., May 1952, 241-244.

Author makes various assumptions about stresses in drawing and extrusion with rough dies and shows that if the coefficient of friction is constant the die geometry is determined. He concludes that this design corresponds to "uniform flow" conditions.

AMR #135 (1955)

178. Kanninen, M.F., and Florence, A.L., "Traveling forces on strings and membranes," International Journal of Solids and Structures 3, 2, 143-154 (Mar. 1967).

The use of explosives to simulate distributed impulsive loads is investigated theoretically for the stretched infinite string and stretched infinite membrane. It is shown that practical explosives above detonation velocities generally supersonic with respect to the string and membrane wave speeds which are based on the initial tension in the member. Criteria are established which permit one to conclude that uniform velocity distributions are produced by the explosive loading.

Reviewer wonders whether the tension is always constant in the experiment described but this does not detract from present analysis.

AMR #7809 (1967)

180. Kawashima, S., and Kimura, H., Measurement of the internal friction of metal wire ropes through the longitudinal vibration, Mem. Fac. Engng. Kyushu Univ. 13, 1, 119-130, 1952.

Logarithmic decrements in free longitudinal vibration at low and medium stress levels were measured for several wires and stranded cables. Specimens were approximately 12 ft long, were clamped at the

upper end, and were loaded at the lower end by weights to various steady axial stresses. Longitudinal vibrations were initiated by an electromagnet, and displacements were measured by an electrical capacitance-type gage and were recorded vs. time. Free vibration frequencies were of the order of 10 cps. Curves showing logarithmic decrement vs amplitude for various axial loads are given for several types of wire rope, and are compared with values obtained for the wire itself. For the steel and copper wires tested, the logarithmic decrements were partically independent of axial load, while for the multiple-strand wire ropes, the decrements were markedly reduced as the axial load was increased. Measured decrements vary from minimum of 0.001 for the steel wire to 0.4 for a 1 1/4-in. 6-37 hempcore steel-wire rope at low stress levels.

AMR #508 (1953)

181. Kenyon, J. N., "A Corrosion Fatigue Test to Determine the Protective Qualities of Metallic Plating," Proceedings of the ASTM, 1940, Vol. 40, pp. 705-714.

The author describes a corrosion-fatigue test for determining the degree of protection afforded by metallic coatings on steel wire. The wire tested was 0.037 in. in diameter, and was a sample of that used to reinforce the beading of rubber tyres. For this purpose a stress-reversal machine was used in which a length of the wire was bent to arc curvature and rotated by an electric motor, a 7.5-in portion of the arc dipping into a bath of oil, distilled water, or salt solution. The fatigue limits for 10^7 cycles of stress of uncoated and copper-zinc coated wire tested in a non-corrosive oil were practically identical. In distilled water, copper-zinc plated wire was much superior to unplated wire, and was also superior to bronze-plated wire. Bronze-coated specimens tested in oil after storage for 48 hr. in distilled water lost about 65 per cent of their original tensile strength after 10^7 cycles of stress and this was found to be due to embrittlement, but this embrittlement did not occur in specimens that had been galvanized prior to bronze plating.

182. Kenyon, J. N., "Fatigue properties of steel rope," Mater. Res. and Stand. 2, 7, 553-556, July 1962

Paper describes the results of a test on the fatigue properties of steel rope wire taken from seven brands of commercial plow steel rope. The tests were performed by a method derived by the author as reported in ASTM Proc. 35, II, (1935). The work is a tentative suggestion for quality standard of rope wires. Neither attempt nor [illegible] [illegible] the fatigue [illegible] [illegible] [illegible] service [illegible] [illegible]tions

AMR #3354 (1963)

183. Kirsanov, N.N., "Calculation of single-span suspension bridges for sag (in Russian)," Sb. tr. Mosk. inzh.-stroit. in-ta no. 1o, 48-64, 1956; Ref. Zh. Mekh. no. 3, 1957, Rev. 3658.

A method of calculation is described for single-span suspension bridges with a rigid stiffening truss of constant cross section, with consideration of the displacements of the suspension cables and the stiffening truss. The calculation formulas for the flexures, angles of rotation, bending moments and side forces have been obtained by solution of the known differential equation for suspension bridges by the method of initial parameters. To facilitate solution, tables are given for the functions entering into the corresponding expressions. Two numerical examples are given.

AMR #4956 (1958)

184. Kloppel, K., and Weihermuler, H., "Nonumiformity of stresses in prestressing cables (in German)," Stahlbau 23, 4, 77-80, Apr. 1954.

Paper discusses the slackening of stresses in prestressed steel members that change direction, and lose tension by friction at the points of direction change. Authors call attention to the influence of vibrations on the stress distribution in such members.

Experimental results are compared with an analysis based on the decrease of tension in a cable rolled on a cylinder of given radius. Authors show the incorrectness of the calculation procedure which assumes equality of the stresses at the two ends of a cable prestressed from only one end. In symmetrical stretching, similar discrepancies arise.

Authors also prove that it is not possible to eliminate the non-uniformity of stresses even by applying an initially higher stress, and then by slackening. On the contrary, slackening of the stressed end caused great variation in the force distribution for differently directed cable lengths. They show experimentally that the stresses can be made uniform only by virbrating the structure, or by a smilar procedure.

Reviewer agrees with authors that special constructional techniques are required to control the stresses in prestressing cables which change direction, and also that design procedure should take into account the stress variations which may occur in elements of the type under consideration.

AMR #1613 (1955)

185. Kokado, J. and [illegible]. Fujinaka, "Inspection of Internal Impairments of Steel Wire Rope by Electromagnetic Detecting Method", Memoirs of the [illegible], Vol. 11. [illegible] Part 2, April 19[illegible].

186. Komarov, M.S., ans Stolyarchuck, V.F.," Determination of the dynamic loading on a hoist rope during starting (in Russian)," Nauch. zap. Lvovsk. politekhn. in-ta no. 29, 3-12, 1955; Ref. Zh. Mekh. no. 10, 1956, Rev 7084.

The dynamic forces in the hoisting and tail ropes of a hoist (lift) are determined. The starting moment for hoisting the load is discussed. The weight of the ropes and change in length of the tail rope, and their rigidity as starting, are neglected. The rotating parts of the hoist are regarded as an equivalent mass M_1, referred to the radius of the rope drum. The excess force F by which the system is set in motion, and which is applied M_1, is regarded as constant.

On these assumptions, the problem is resolved into the solution of a system of three differential equations of the second order with constant coefficients. As a result, comparatively simple expressions are obtained for the forces in the hoisting and tail rope. In the particular case considered the stress in the hoisting rope (correcting the misprints) is determined by the expression:

$$F_2 = \frac{Fc_2}{m_1(K_1^2-K_2^2)}\left[\frac{1}{K_2^2}\left(\frac{c_3}{m_2}\;\frac{c_2+c_3}{m_1}-K_1^2\right)\cos K_2 t - \frac{1}{K_1^2}\left(\frac{c_2}{m_2}+\frac{c_2+c_3}{m_1}-K_2^2\right)\cos K_1 t\right] + Fm_2/(m_1+m_2+m_3)+Q \qquad [*]$$

in which K_1 and K_2 are the roots of the characteristic equation, m_2 and m_3 the masses of the load and counterweight respectively, c_2 and c_3 the rigidities of the hoisting and tail rope respectively and Q the ultimate weight of the load.

Analyzing this expression, the authors find two possible maximum values of the forces in the rope, at $\cos K_1 t = \cos K_2 t = -1$, and at $\cos K_2 t = -\cos K_1 t = 1$.

It must be noted that determination of the maximum stress by these means may prove to be impossible if (1) the ratio K_1/K_2 is an irrational number (when $\cos K_1 t$ and $\cos K_2 t$ cannot simultaneously assume the value of ± 1 at any instant of time t); (2) the ratio $K_1/K_2 = n_1$, n_2 has one of the integers n_1 or n_2 odd integers, while the coefficients of the cosines in Eq. [*] are of opposite sign; (3) the ratio $K_1/K_2 - n_1/n_2$ odd and the other even, while the coeficients of the cosines are negative.

AMR #2476 (1958)

187. Koppl, G.," Severe mechanical stresses imposed on single-column isolators," Brown Boveri Rev. 49, 6, 226-229, June 1962.

The mechanical effect of short circuit in a two-wire conductor

suspended from single column isolators is studied. The wires, separated at equal intervals by spacers, are hung from isolators in a form of flat catenary. In case of short circuit the mutual attraction of the wires is increased, causing a decrease in the sag of the catenary and a resultant increase of the tension in the conductors and the pull on the isolators. A differential equation for the lateral displacement of the wires as a function of time is written down and is solved for one particular set of conditions. A graph is plotted showing the variation of the pull with an assumed number of the inter-wire spacers.

AMR #2649 (1963)

188. Korber, F. and Hempel, M., "Influence of Cold-Work and Ageing on the Behavior of Steel Under Alternating Stress," Mitteilungen aus dem Kaiser-Whilhem-Institut fur Eisenforschung, 1935, Vol. 17 No. 22, pp. 247-257.

The effect of the mechanical and termal ageing of cold-worked steels on the static properties, the bending and tension-compression fatigue strength, the changes in the damping capacity of the material, and metallographic and X-ray tests are reported on. A 5 or 10 per cent. cold deformation without ageing reduces the notch toughness considerably; thermal ageing decreased in still further. For both steels tested (carbon 0.02 per cent. and 0.39 percent.) and both degrees of cold work the notch toughness of the mechanically aged specimens (by stress alternations) approximated to the value for the cold-worked unaged specimens. This suggests that the effects of the thermal and mechanical ageing of cold-worked steels arise from different causes. The inflence of the two ageing treatments, after different degrees of cold-working, on the tensile strength, yield point, and fatigue strength of the two steels was not the same; for both degrees of cold work, there was no difference between the values of these properties of the mechancially aged and thermally aged specimens of the 0.02 per cent. carbon steel; in the case of the 0 39 per cent. carbon steel, the properties after mechanical and thermal ageing were the same for 5 per cent. cold work, but after 10 per cent. cold work thermal ageing was superior to mechanical ageing In the damping measurements the dependence of the damping on the amplitude, time and deformation was determined. For both materials the stable damping of the 5 per cent cold-worked and thermally aged specimens was less tha that of those aged mechanically; after 1o per cent. cold work the condition was reversed. No alteration of structure due to tensile-compressive stressing could be observed. By the X-ray reflection method, the change of the width of the interference lines due to cold-working, and also before and after tensile-compressive stressing, was examined. The line width increased with the cold work (no alternating stressing). For the 5 per cent. cold-worked [illegible] aged by eigher method, there was no clear indication of any change in the line width with and without alternating stressing, but with 10 per cent. cold-worked specimens, both unaged and

thermally aged, the sharpness of the lines increased after alternating stressing.

189. Korbut, V.M., "Influence of dosage of surface-active substance on the surface plasticization of a metal during drawing," Soviet Phys.-Doklady 4, 1, 176-178, Aug. 1959. (Translation of Dokladi Akad, Nauk SSSR (N.S) 124, 1, 72-74, Jan./Feb, 1959 by Amer. Inst. Phys., Inc., New York, N. Y.).

From observation that shear stress in surface layer of wire during drawing decreases in presence of surface active lubracant, author concludes that lubricant migrates into two-dimensional surface defects. Further decrease with increasing deformation, temperature and number of molecular layers of agent on surface is regarded as support for this assumption.

To reviewer development of such defects seems unlikely under normal conditions. Observations may be explained on basis of pure surface friction only.

AMR #5132 (1960)

190. Korbut, V.M., Veiler, S. Ya., and Likhtman. V.I., "Significance of adsorption insteractions and the bulk-mechanical properties of lubricant layers in the processing of metals under pressure," Soviet Phys.-Doklady 5, 1, 148-150, July/Aug. 1960. (Translation of Dokladi Akad, Nauk SSSR (N. S.) 130, 2, 307-309 by Amer. Inst. Phys., Inc. New York, N.Y.).

It has been shown in papers put out by authors' laboratory that, whith deep plastic deformation in the presence of surface-active liquid lubricant layers, the so-called adsorption plastification of the metal takes place in a very fine surface layer. The plastification effect, which is elicited by adsorption of the surface-active components of the lubricant, is characterized by considerable reduction in the shear stress of the fine layer of processed metal.

The presence of a plastified layer promotes the equalization of the volume flow of metal, reduces the work of deformation, and increases the capacity of the metal for being worked under pressure; here, the additional shear deformation due to friction is localized in the plastified layer.

A solid, but sufficiently plastic, lubricant film deposited on the surface of the processed metal, the shear stress of which is considerably less than in the base metal, plays the same role as the plastified layer.

AMR #1904 (1961)

191. Kovalev, N.N., "Deformability qualities of prestressed reinforcement made of steel cables (in Russian)," Beton i Zhelezobeton no. 6, 245-249, June 1963.

Herewith a report on investigations of cable properties for use in prestressed concrete. Young's elasticity modulus has been compared to the cable's apparent Young "modulus" and the permanent strain is given in tabulated form. The author claims that he succeeds in eliminating the effect of permanent strain through an initial prestress up to 110% of the expected stress.

Reviewer remarks that research on creep and permanent strain requires a long time study, which has been prescribed in the article. Therefore, reviewer's opinion is that the data given should be used with some reservation.

AMR #7178 (1964)

192. Koval'skii, B.S., "Theory of multiple winding of rope (in Russian)," Doklady Akad, Nauk SSSR (N.S.) 74, 3, 429-432, Sept. 1950.

The axial tension in any turn of rope-winding decreases with its radius r. Therefore, the decrease of length of each r due to the pressure exerted by the terms of greater r produces the decrease of the axial tension in a given turn. Author introduces the notion of a coefficient of transversal compression K and derives the integral equation for the axial tension in the turn of the rope with radius r divided by the breath of the rope. Author uses the above equation as a basis for introducing diagrams, assuming a priori a certain law of relationship between axial tension and radius, which show that taking into account the transversal deformations of the rope greatly decreases the axial tension in each turn of winding. The transversal deformation of the rope also has great influence on the pressure exerted by the rope on the drum. In this example, the pressure of the rope on the drum, by taking into account the transversal deformations of the rope and of the drum, is 50 kg/cm² and, by neglecting these deformations, is 437 kg/cm².

AMR #381 (Feb 1952)

193. Kozak, R., "The strength of the concrete and bound stressing wires of stressed concrete structures affected by pulsating forces (in French)," Acta Technica 44, 1/2, 91-110 (1964).

AMR #6501 (1967)

194. Kuzhiy, A.I., and Shevelo, V.M., "The influence of incomplete elasticity on the dynamic forces in a rope of variable length, analyzed by an asymptotic method (in Russian)," Prikl. mekhanika 1, 1, 41-50, 1955; Ref. Zh. Mekh. 1956, Rev. 4845.

The purpose of the present investigation is to demonstrate that the incomplete elasticity of a cord of variable length has a material influence both quantitatively and qualitatively on the behavior of the dynamic forces arising during the lifting of the load. It is assumed in this investigation that the law of variation of the hoisting rate (rotational speed of the winding drum can be described by a trapezoidal broken line. Qualitative analysis leads the author to the conclusion that for a given hoisting rate $v_c = v_0 + at$ it is possible to indicate a particular limiting value of the coefficient of incomplete elasticity α_{np} at which, for all values of $\alpha < \alpha_{np}$, the forces in the cord will grow, while for $\alpha > \alpha_{np}$ they will decrease. The coefficient α characterizes the absorption of energy by the oscillations of the cord. N.V. Zvolinskii, USSR Courtesy Referativnyi Zhurnal (Translation, courtesy Ministry of Supply, England).

AMR #3560 (1957)

195. Lamb, H., Statics, Cambridge Univ. Press, England, 3rd Ed., 1928.

196. Landweber, L., "Hydrodynamic Forces on an Anchor Cable" DTMB Report R-317, Nov. 1947.

This report presents curves from which the magnitude and direction of the tensions in the anchor cable can be determined when the drag of the ship, velocity of the current, depth of the water and type and length of the anchor cable are known. Formulas are given for ship drag, current parameter, breaking strength of wire-rope and chain cables, safe working loads on cables and holding power of an anchor

197. Landweber, L. and M.H. Protter, "The Shape and Tension of a Light Flexible Cable in a Uniform Current," J. of App. Mech. pp. A121-A126, 1947.

This paper deals with several cases of towing cable in which the frictional forces as well as the normal forces are taken into account in determining the configuration of the cable. The weight of the cable is neglected. Several towline situations of practical interest are considered as applications of use of equations and curves presented in the paper

198. Laura, Patricio A and Mario J. Casarella, Discussion of the paper "A Three Dimensional Dynamic Analysis of a Towed System" Journal of Hydronautics (Vol. ?, No. 4, by Schram and Reyle) Vol 3, 1969.

199. Laura, P.A and Casarella, M.J., "A Survey of Publications on Mechanical Cables and Cable Systems," Report 68-1, Themis Program No. 893, N00014-68-A-0506-001, Institute of Ocean Science and Engineering, The Catholic University of America, Washington, D.C., December 1968

200. Laura, Patricio A ; Hendrikus Vanderveldt and Paul Gaffney, "Acoustic Detection of Structural Failure of Mechanical Cables," Journal of the Acoustical Society of America, 1969 (Letter to the Editor).

201. Leyland, C L , Rao, A R S., and Ramsdale, H.A., "Experimental investigation of torsion in stranded mining wire ropes," Instn. mech. Engrs. Proc. (B) 1B, 8, 323-336, 1952-1953.

Modulus of rigidity is primarily dependent upon construction (number of wires and strands), varies somewhat with type of lay and lubrication, and is rather independent of load and diameter. An approximation may be had by dividing the modulus of rigidity of steel by the total number of wires and multiplying by the cosine of the helix angle This gives good results except when more than 75 wires are used, in which event friction apparently leads to higher values

Considerable data are provided for angular deflection in laying and unlaying direction, rotation due to tension, and extension due to rotation.

AMR #3158 (Oct 1954)

202. Leites, A.V., "Testing Cables and Wire," Zavodskaya Laboratoriga, 16, 6, 1950, p. 758 (in Russian)

Difficulties in preventing the method of securing wire or cable specimens in tensile tests from influencing results is considered.

203. Lennox Jr., T.J., "Corrosion Analysis of 304 Stainless Steel Wire Rope and Fittings from a NOMAD Buoy Mooring System After 34 - Months Continuous Service in the Gulf of Mexico," NRL Memorandum Report 2405, September 1969

Samples studied of a 1250 ft length of stainless steel wire rope

(3/4 in. diameter - 6 X 19 Warrington - IWRC 7 X 7) and associated stainless steel tube thimbles and cable clamps. This rope was in continous use for 34 months in the Gulf of Mexico as the upper portion of the Nomad buoy mooring system. No significant corrosion was reported for the top 1000 ft., which was well lubricated and cathodically protected. However, the lower 250 ft., which was jacketed with neoprene for abrasion protection, was relatively severely corroded.

Recommended that mere inspection of external wires of stainless rope is not adequate to determine extent of corrosive damage since primary mechanism of corrosion in stainless steel is by crevice corrosion or tunneling. Also recommended that in critical applications the wire rope be replaced at first sign of rope deterioration.

204. W. Lethersich, "The measurement of the coefficient of internal friction of solid rods by reasonance method," J. appl. Phys. 1, 18-22 (Jan. 1950).

It is usual to assume that longitudinal resonant frequencies of a cylindrical rod are not affected by presence of internal friction. This assumption is sufficiently accurate for metals and certain crystals such as quartz. It is not accurate enough for measurement on plastics, the materials of interest to author. Paper is devoted to introduction of second-order approximations in formulas for computing coefficients of viscosity from vibration data. In the main body of paper it is assumed that, after Stokes, viscous effects arise only from time rates of shear strain. Near the end an additional treatment is given which includes friction arising from time rates of volume changes. It is shown that neglect of second approximation to resonant frequency will introduce errors in internal damping calculations of the order of 12 per cent, whereas its inclusion will reduce them to 1 per cent. It is also pointed out that existence of a volume viscosity can be detected by measurements upon same specimen first with torsion waves, and then with longitudinal. Paper is recommended as a good summary of appropriate formulas for calculating viscous coefficients from vibration experiments which determine width of reasonance as conventionally defined.

AMR #1945 (1950)

205. Lex, W.I., "Operation, Maintenance and Inspection of Wire Rope", U.S. Coast Guard, Proceeding of the Merchant Marine Council, pages 91-96 (May, 1968).

206. Lex, W.I., "Tests on this Wire Rope Fatigue Machine Proved that Lubricants do Penetrate Wire Rope," Eng. M. N. J., 1954, 155, June, ppl 96-98.

Tests show value of correct external lubrication for ropes. Fibers

preserved longer; corrosion retarded; friction reduced, fatigue onset delayed, lives prolonged for ropes, drums and sheaves.

207. Lin, T.Y.,"Cable friction in post-tensioning," Proc. Amer. Soc. civ. Engrs. 82, ST 6, (J. Struct. Div.), Pap 1107, 12 pp., Nov 1956.

AMR #1788 (1957)

208. Lindstrand, E.,"Wire drawings - a literature survey (in Swedish)," Jernkontorets Ann. 142, 3, 105-127, 1958.

AMR #4544 (1958)

209. Little, Arthur D., Inc., "Stress Analysis of Ship-suspended Heavily Loaded Cabled for Deep Underwater Emplacements", Prepared for Bureau of Ships, August 1963.

210. Litton Systems Inc., McKiernan Terry Marine Div., "Study and Design of Cable Fairing for Drag and Mechanical Reliability Improvement", E4-9250, July 1964.

211. Lueg, W. "Improving the Quality of Drawing Tools by Controlling Die Profile by Modern Measuring Methods," Stalh and Eisen, Vol. 71, pp. 157-170 (1951).

212. Lueg, W., and Treptow, K.-H.,"Lubricants and lubricant carriers in steel wire drawing (in German)," Stahl.u. Eisen 72, 8, 399-416, Apr. 1952.

213. Lueg, W., and Treptow, K.H.,"New investigations on the drawing and "pushing-in" of steel rods. Part 1, Part 2, (in German)," Stahl u. Eisen 75, 3, 1620169, Feb. 1955; 75, 12, 769-776, June 1955.

Part I describes a comparative experimental and theoretical study of the forces required in (a) pushing round bars into, and (b) pulling them through a drawing die. Authors show that, for a constant percentage reduction of cross section, the force for pushing (extrusion) is higher than for normal drawing; furthermore, that the specific drawing (extrusion) force decreases gradually with increasing bar cross section and approaches an asymptotic value.

In part II, the elastic distortion (diametrical expansion or contraction) of the bar as it leaves the die was studied. This elastic strain was generally positive, but for any specific die angle it varied

with the length of the cylindrical die extension, its value invariably reaching a minimum at a certain length of said extension. The minimum was either slightly positive or negative, depending on the die angle.

AMR #2949 (1956)

214. Lutchansky, M., "Axial Stresses in Armor Wires of Bent Submarine Cables," Trans of the ASME, Journal of Engineering for Industry, August 1969.

A mathematical model is presented to describe the axial stresses induced in the helically wound armor wires of a submarine cable bent over a drum. The model represents the wire-core intraction and yields a simple description of the stress concentration at a rigid inclusion such as a clamp or apparatus housing. "Free field" expression obtained for stresses away from an inclusion also obtained and shows effect of entire range of interaction stiffnesses from frictionless slip to infinite interaction shear stiffness. At the latter limit beamlike outer fiber stresses are produced. Beamlike stresses also produced for limiting case of infinitesimally thin wires and infinitely long lay-length (wires running parallel to cable axis).

215. Lyst, J.O., and Babilon. C.F.," Detecting fatigue cracks in notched fatigue specimens by changes in electric resistance," Mater. Res. and Stands. 2, 6, p. 485, June 1962.

This paper describes a method of detecting cracks, in a fatigue specimen, by measuring the changes in the eletrical resistance of the surface by direct-current conduction. Both resistance and crack length were observed to increase as fatigue life was consumed. In rotating-beam fatigue tests, cracks propagated slowly until the crack covered about 5 percent of the cross-sectional area, after which the rate of propagation increased rapidly to failure. Fatigue cracks as small as 0.005 in. deep could be detected in 0.330-in diameter specimens by this method, and cracks could be detected when the change in resistance was a small as 2.5 percent.

AMR #7041 (1962)

216. Mack, C.," The tension in strings wrapped slantwise round cylinders when friction is proportional to a power of the normal reaction," Brit. J. appl. Phys. 7, 8, 294-296, Aug. 1956.

Paper derives expressions for string tension and normal reaction for title string, assuming that limiting firction acts (1) in direction of string, and (2) parallel to axis of cylinder.

AMR #418 (1957)

217. Majors, H., Jr.," Studies in cold-drawing. Part I. Effect of cold-drawing on steel; Part II. Cold-working 2S-0 aluminum," Trans. ASME 77, 1, 37-48, 49-56, Jan 1955.

In both papers the effect of drawing 1-in. diam rods down to 11/16 in. in various sequences is reported. Properties investigated were tensile, torsion, and hardness. Microstructure was studied and residual stress measurements made. In the case of steel, a limited number of impact tests were carried out to investigate the effect of drawing sequence on the transition temperature. For both metals it is concluded that the properties are affected in a similar manner. The tensile yield strength has very little effect, and sequence in drawing has no effect on the true stress-strain diagram in tension. The results of the torsion tests are inconclusive, and further work is suggested. Hardness is independent of drawing sequence and no variation in hardness across a section was observed. Microstructure was found to be uniform across section and very little affected by sequence. Residual stress was found to be greatly affected both in magnitude and distribution.

AMR #883 (1958)

218. Mak, S.L., Tulenkov, F.K., and Shteinberg, L.B ," A machine for fatigue testing rope wire," Industr. Lab. 28, 1, p. 117, July 1962. (Translation of Zavod. Lab 28, 1, p. 114, Jan 1962 by Instrument Society of America, Pitsburgh, Pa.).

Paper describes briefly a wire testing apparatus built on a lathe, which is claimed to accurately reproduce stressed condition of wires of a rope.

AMR #4471 (1964)

219. Markland, E.," The deflection of a cable due to a single point load," Phil. Mag. (7) 42, 322, 990-996, Sept 1951.

Paper gives method for the calculation of influence coefficients for vertical loads and deflections of a uniform cable These coefficients, which are functions of the applied load, are required for the analysis of suspension bridges after the manner of A.G Pugsley [J. Inst. civ. Engrs. 32, p. 226; Struct. Engr. 27 p 327]. Experiments on a 5-ft chain agree very well with the calculations

AMR #1025 (1952)

220. **Martin, D E.,"An [illegible] criterion for low-cycle fatigue," ASME Trans. 83 D (J Basic Engng) 4, 565-571, Dec 1961**

A low cycle fatigue criterion is proposed which employs as an index of damage the portion of the plastic-strain hysteresis which is associated with the work-hardening segment of the stress-strain [illegible]. This damage work-energy relation provides a theoretical [illegible] for the plastic strain-cycle life equation

$$N^{\frac{1}{2}} \Delta \varepsilon = C$$

which was previously advanced empirically

AMR [illegible]660 ([illegible])

221. Ma[illegible], W "The [illegible] Steel Wire Under Stresses of Very Small Duration", Proc of the Institution of Mechanical Engineers, Vol. 128, 1934, pp. [illegible]

222. McLoad, K W and W [illegible] Bowers, "Torque Balanced Wire Rope and Armored Cables", transactions of the 1964 Bouy Technology Sumposium

Torque-balanced wire ropes and armored cables offer signigicant advantages by reducing stre[illegible]h and the amount of energy stored in the cable The paper discusses cable properties and operational problems A figure of merit Q is defined as

$$Q \simeq E \left(\frac{S}{\rho^1}\right)^2$$

where

E: Modulus of Elasticity

S: Ultimate Strength

ρ^1: effective density of material in water

By this measure, titanium is the best material. Steel and dacron follow. The parameter [illegible] defined as

[illegible]

[illegible] stretch)

223. **Medvedik, S L ,"Dynamic stresses in cables of cranes (in Russian)," Teoriya Mashin i Mekhanizmov n. 96 [illegible], 105-119, 1963**

This is an analytical and experimental study. The crane mechanism is reduced to a linear system of spring and masses The results are

useful for the design of cranes and other weight-lifting equipment.

AMR #2298 (1966)

224. Meebold, R., Cables and their practical use [Die Drahtseile in der Praxis], 2nd rev. ed., Berlin, Springer-Verlag, 1953, vi + 108 pp., 121 figs. DM 12.

Book deals with construction and application of wire ropes Under construction, following items are covered: Principal types of wire ropes; strand arrangements; strength and design of ropes; wire materials; ratio of wire to rope diameter; number of wires in strands and wire arrangements Under application, the following items are covered: Life of wire ropes as affected by nature of service; methods of fastening rope ends; methods of binding ropes; wear, loosening, untwisting, and distortion in ropes; types of wire-rope failures; corrosion in wire ropes and prevention of corrosion. A brief bibliography completes the book.

AMR #1319 (1955)

225. Megyeri, J.,"Exact calculation of loading on cable supports (in Hungarian),"Melyepitestudomanyi Szemle 7, 11/12, 375-381, Nov./Dec. 1957.

Distinction is made between actual cable tension and its horizontal component. Effects of wind loads and of friction at the supports are considered. Deviation from results of approximate analysis is found greatest when concentrated loads are applied midway between consecutive supports. Numerical tables are given, and also a nomogram for finding critical load combinations.

AMR #73 (1959)

226. Mehta, P R , "Static and Dynamic Stresses in Overhead Conductors" Spring Conference, Transmission and Distribution Session, Cheyenne, Wyoming, April 22, 1968.

227. Meier, J H., "Energy Transmission by Stress Waves in Prismatical Bars," Experimental Mechanics, May 1965, pp. 135-141.

This paper deals with energy transmission by stress waves in prismatical bars. Experiments were conducted on straight and curved bars. The effects of cross-section impedance mismatch and length mismatch of impacting bars in studied. The author is apparently unaware of the technical literature available on vibrations and effects of dispersion in curved bars.

228. Michel, Douglas, Pikul, R.P. and Kosser, A.F., "Forces due to Travelling and Standing Waves in Cables" Interim Report No. C-70; The Kaman Aircraft Corporation, August 1954.

If an antenna-supporting vehicle is disturbed from its steady state flight by a gust, then it, in turn, will disturb the end of the cable to which it is attached. This disturbance will travel down the cable to the mooring point, reflect and travel up the cable to the vehicle and disturb it again. It is clear that the cable dynamics must be included when designing an automatic position stabilizing device for the vehicle. The purpose of the present report is to devise methods for determining the transient force at the mooring point due to a disturbance of the vehicle.

229. Middleton, G.W. and J.W.N. Fead, "Fundamental Cable Analysis". Developments in Mechanics, Vol. 4, Johnson Publishing Co, (Proceedings of the Tenth Midwestern Mechanics Conference) pp 631-645.

This study contains equations which are derived for simple cables giving a direct solution under the condition of uniform horizontal distribution of dead, ice, and wind loads. This analysis is different from previous cable treatments in that it specifies the maximum force in the cable rather than assuming the amount of sag in the cable Equations are also derived for cables which carry concentrated loads in addition to the above loads. When the maximum force which is to appear in each cable of an antenna system is specified and the cables are considered as inextensible, it is proved that the system is determinate.

The equations are not linear, and an iterative process is required to obtain a solution of the equations. Such a process is described here. The results are listed for comparison, and these were obtained by computation and by measurement from a model.

230. Mimoso, E., Aida, T., and Higami, H., "Fatigue Tests of Wires for Wire Rope," Sulyokwal - Shl, 1954, 12, Oct., 378-395 (In Japanese)

Performed rotating bend fatigue tests on rope wire of two sizes and same strength. Impact tensile strength dropped suddenly after a certain number of cycles; this number was shown to be lower for the thicker wire which also had a lower endurance and fatigue limit.

231. Military Specification - Cable, Electronic, Tow, for Submarine Application, MIL-C-23812A (Ships), 15 Feb. 1965.

232. Miller, Eugine and W.C. Webster*, "An Analysis of Large Object Lift Systems," ASME Underwater Technology Division, 1967 National Conference.

The raising (or lowering) of a very large object, such as a submarine, in the open sea is an extremely difficult and costly operation. A major problem is the large seaway induced forces and motions. This paper deals with analysis and control of these forces in two types of large object lift systems. One system involves use of two surface ships lifting a submarine with cables. The other system consists of standard winches on minimum response surface floats instead of conventional surface ships.

* See also: Technical Report 613-1; Hydronautics Incorporated, Dec. 1966.

233. Moore, H.F., "Fatigue Testing of Wire," Wire and Wire Products, Vol. 12, May 1937, pp. 235-236.

Discusses various types of machines for fatigue testing of wire.

234. Montague, P.,"Load distribution in overhead stranded conductors," Inter. J. Mech. Sci. 2, 3, 277-293, Apr. 1961.

Author attempts to forecast the load taken by each strand of a steel-cored aluminum conductor at different total cable loads by considering the fundamental load-strain characteristics of the steel and aluminum elements. Temperature and creep effects are not considered. Cold working may influence experimental values.

AMR #107 (1962)

235. Moorman, R.B.B.,"Continuous prestressing," Proc. Amer. Soc. civ Engrs. 81, Separ. no. 588, 21 pp., Jan. 1955.

Author discusses the influence of posttensioning on statically indeterminate structures, such as continuous beams, by introducing equivalent loads corresponding to the bending moments caused by an eccentric cable. Cables with parabolic curvature are studied especially, and numerical examples are given together with a recommendation for analysis and design procedure.

AMR #1656 (1955)

236. Morales, R.C., Shear-volume method of solving tensions in cables, Journal of the Structural Division, Proceedings of the American Society

of Civil Engineers 94, ST 1, 111-118 (Jan. 1968).

A simple expression is given for the length of a cable in terms of its span length, the tension in the cable, and the "Shear-volume," the last being the integration of the square of the transverse shear force V over the span of the cable. The derivation assumes small sag of the cable and is based on the usual relation V = dM/dx in which M is the bending moment.

AMR #7182 (1968)

238. Nakamura, K., and Nakamura, Y., "Low temperature annealing of drawn wire," J. mech. Lab. Tokyo 2, 2, 25-28, 1956.

Paper presents results of a limited investigation conducted upon medium-alloy patented steel wires, such as might be used for suspension bridge cables, to determine effects of temperature rise during drawing and effects of various sequences of drawing and low-temperature annealing. Data indicate that tensile strength increases and ductility decreases with increase in temperature during drawing. Data also indicate that a final low-temperature annealing following drawing operations will increase tensile strength significantly; apparently this occurs whether or not the patented wire was fully annealed before drawing.

AMR #2939 (1957)

239. Nishioka, T., "Surface Condition and Fatigue of Wire Rope," Wire World International, 8 (3), 67-73 (May - June 1966).

240. Nowinski, J., "A series of experiments concerning the effect of scale on the rupture of steel wires (in Polish)."

The scale effect, i.e., the effect on strength of absolute dimensions of structural parts, and the dispersion of the strength itself have a common background due to natural nonhomogeneity of materials. In already published papers, phenomena having a statistical character are explained for brittle materials. The results of the author's experiments concerning the rupture of 5-cm and 50-cm steel wire samples, 4.5 mm in diameter, lead to the conclusion that the scale effect appears also for nonbrittle materials.

AMR #494 (1958)

241. Nowinski, J. L., "Transverse perpendicular impact on a cable of a highly elastic material," AIAA Journal 5, 2, 332-333 (Technical Notes), (Feb 1967).

By the stress-strain relation furnished by the theory of finite elastic deformation, author derives and discusses the formulas for the velocity of propagation of longitudinal and transversal waves and for the velocity of impact in a cable of rubber-like materials.

AMR #4728 (1967)

242. O'Brien, W.T., Behavior of loaded cable systems," Journal of the Structural Division, Proceedings of the American Society of Civil Engineers 94, ST 10, 2281-2302 (Oct. 1968).

Author analyzes load-deflection characteristics of a freely suspended cable system subjected to a point load in any direction. Effects of various system parameters are examined. Results are given in equation, tabular, and graphical form. Paper is theoretical, not experimental. Application is to suspension bridge cables and similar systems.

AMR #6977 (1969)

243. O'Brien, W.T., and Francis, A.J., "Cable movements under two-dimensional loads," Proc. Amer. Soc. Civil Engrs. 90, ST 3 (J. Struct. Div.) (Part 1), 89-123, June 1964.

The problem of determining the deflected shape of a suspended cable subjected to a general two-dimensional system of gradually applied concentrated loads is quite involved. The tedium results from the nonlinear stiffness characteristics of a suspended cable.

The authors have nearly solved the equations of static equilibrium for the various load points by the process of successive approximations. In their analysis they considered all the effects such as temperature change, yielding of the supports and slipping of the cable at the support. The three numerical examples fully demonstrate the use of the method. The results are tabulated and compared with the ones obtained using the existing procedures. It is quite evident that the features of the method of this paper are greater accuracy and reduced computational effort. The authors also included two appendices in which they derive the basic equations of suspended cables and correction formulas.

The paper is self contained, analytical in its approach and very easy to understand.

AMR #5614 (1964)

244. O'Brien, T.,"General solution os suspended cable problems," Journal of the Structural Division, Proceedings of the American Society of Civil Engineers 93, ST 1, 1-26, (Feb. 1967).

The problem of cable displacements under an out-of-plane system of gradually applied concentrated and distributed loadings is presented by the author with the thoroughness of a PhD. dissertation. This study is continuation of a previous one in which in-plane system of loading was considered [O'Brien, W.T., and Francis, A.J., AMR 17 (1964), Rev. 5614].

The method of analysis of the paper is general and as such can be used for the solution of any suspended cable problem. Equally important, very good agreement was obtained with tests performed on experimental models.

The approach used, in the paper, is basically analytical The basic formulations of the problems are presented very clearly but the computational procedures are not sufficiently detailed.

The level of maturity or experience expected of the reader is high.

AMR #925 (1968)

245. Okubo, H.,"The torsion and stretching of spiral rods - I," Quart. appl. Math. 9, 3, 263-272, Oct. 1951.

An analysis is presented to determine the torsional deformation and stretching of spiral rods. The equations of equilibrium are expressed in terms of displacements. They are developed into forms which are independent of the position of the section, and, therefore, they are independent of one coordinate. Author achieves this by translation and rotation of a system of coordinate axes of a section which is perpendicular to the axis of the helix. By fixing this system of axes to the section, it is translated and rotated about the axis of the helix together with the section along the spiral rod. In this matter, the stress distribution in the section in relation to the coordinate axes is constant for all sections. Differential equations of displacements are integrated for the special case of a small helix angle. Resulting expressions for displacements and stresses contain three arbitrary plane harmonic functions which can be determined when the shape of the section is known. As an application of the general solution, author considers a spiral rod of elliptical cross section and evaluates a numerical example. He arrives at the result that, while shape of cross section of a straight rod is not deformed by twist, the cross section of a spiral elliptic rod changes. The ellipse becomes flatter or rounder depending upon the axial elongation or contraction which takes place in a spiral rod when it is twisted. In solving the same numerical problem for stretching, author finds that the spiral rod is subjected to twist when it is pulled axially. Maximum and minimum normal stresses occur at the ends of the minor and major axes of the ellipse. The maximum shearing stress is at both ends of the minor axis.

AMR #1662 (June 1952)

246. Oschatz, H., "Testing of Wire in Fatigue," Draht, German ed., 1955, 6, Jan., 12-213.

Description of various fatigue - testing machines manufactured by Schenk for tests of wire and springs. Rotating bend, push-pull and programed variable amplitude tests are described.

247. Ostroumov, G.A., "Theory of thermal processes during liquid drawing of wire under steady-state conditions," Soviet Phys. - Tech. Phys. 4, 2, 208-214, Aug. 1959. (Translation of Ah, Tekh. Fiz. 29, 2, 239-247, Feb. 1959 by American Institute of Physics, New York, N.Y.).

Authors consider a liquid metal jet leaving (at $Z = 0$ and velocity V) a furnace, having the temperature of the furnace as exit temperature. In the region $Z > 0$ the cylindrical jet is surface-cooled (heat-transfer coefficient is prescribed). Author determines the temperature distribution as function of Z and r, restricting himself primarily to the slowest decaying term of an infinite series. He also treats the case where, at $Z = 0$, heat of fusion release occurs (the jet freezes), and applies the results to the case of zone melting. Checking of paper is difficult, because author states only results and gives no details of analysis.

AMR #2532 (1960)

248. Otto, P., "Rope creep on sheaves (in Dutch)," Ingenieur 65, 31, W.139-W.146, July 1953.

The forces in a cable before and behind a driven or driving sheave being different, "creep" of cable over part of sheave must occur owing to variation of elogation of cable in contact with sheave. Paper gives theoretical analysis of cable force distribution, amount of creep, and frictional energy accompanying creep. Results are compared with previously published ones, showing some improvements in present analysis; a numerical example of application is given.

AMR #2126 (July 1954)

249. Owada, S., "Calculation of tensile and torsional stiffnesses of single-lay cables," Proc. 2nd Japan nat. Congr. appl. Mech., 1952; Nat. Committee for Theor. appl. Mech., May 1953, 159-164.

Author applies Kirchhoff's thin rod theory to obtain effect of contact pressure on stiffness of cables in a core-side wire cable combination under tension and torsion. Author obtains expressions for these stiffnesses and points out that they agree well with results of experiments.

AMR #2307 (August 1955)

250. Pankratov, S.A., and Volkov, B.N., "Calculation of tensions in long ropes and suspensions," Russian Engineering Journal 46, 12, 29-31 (1966). (Translation of Vestnik Mashinostroeniya 46, 12, 29-31 (1966) by Production Engineering Research Association of Great Britian, Melton Nowbray, United Kingdom).

Bending stress in a pretensioned rope without sag subjected to vibration without damping is investigated. The vibration is assumed to be due to a sinusoidal function $y = Y \sin (\pi x/l) \sin (\Omega t)$ in which y is the transverse displacement, x is the coordinate along the rope, l is the length of the rope, Ω is the frequency, and t is the time. It was found by experiment that the moment of inertia (bending stiffness) of the rope is a function of tension. Equation for bending moment anchorage is given, from which stresses in rope strands can be determined.

AMR #8821 (1968)

251. Pelczynski, T., "A study of cracks in extruded metal (in Polish)," Obrobka Plastyczma 1, 2, 23-40, 1959.

In an extruding process without cracks the condition $Z > r$ must be satisfied (Z = the capacity of metal of cold-working, r the resistance against crushing).

The existing methods of preventing cracks by the choice of the optimum temperature and extrusion velocity enable us to change the quantity r. It is pointed out that the value of Z may be influenced by a suitable form of the die. Experiments are described concerning the extrusion of a brittle alloy through dies of various forms. The test results confirm the efficacy of the new method of preventing cracks.

AMR #5849 (1962)

252. Penkov. A.M., and Vorobeikov, A.M., "Fatigue machine for testing steel cable wires with complex loading (in Russian)," Zavord. Lab. 21, 7, 860-862, 1955; Ref. Ah Mekh. 1956, Rev 5556.

Description of a machine for fatigue tests of a wire of diameter between 0.3 and 3.0 mm for combined loads by tension, bending and torsion, in which the tensile stress is constant, the bending over the arc of the circle of given angle is also variable. The frequency of the cycles is up to 500 a minute.

AMR #2619 (1958)

253. Pepper, P.A., and Streich, J., "The steady, rectilinear towing of a weightless hydrofoil-cable system in a non-uniform stream," Edo Corp. (College Point, N.Y.) Rep. 5709 (Contract No. 3582(00)), 17 pp., Jan. 1962.

AMR #6822 (1962)

254. Peterson, R.E., "The role of stress distribution in fatigue," Experimental Mech L, 4, 105-115, Apr 1961.

255. Peterson, V.C. and Tamor, D., "Tests Show How Sea Water Affects Wire-Strand and Rope," Materials Protection, 7 (5), 32-34 (May 1968).

256. Pode, Leonard, "A method of determining optimum lengths of towing cables," David W. Taylor Mod. Basin Rep. 717, 14 pp., Apr. 1950.

260. Pollock, P.J., and Alexander, G.W., "Dynamic stresses in wire ropes for use on vertical hoists," "Wire ropes in mines"; Proc. Conf. Ashorne Hill, Sept. 1950, Instn. Mining Metall., London, 445-462, 1951. $7.

Employing Laplace transform, author solves the equation of motion of an elastic rope of free length L and mass mL, supporting a cage of mass M at the bottom and moving vertically downward when a deceleration is applied at the top by means of brake drum. Then he obtains expressions for dynamic tensions in cases of constant rate and steadily increasing rate of deceleration, etc., damping and change of length of rope during the braking period being neglected. Perfect reflection of stress waves at the drum has been assumed.

Author deduces that anything in the nature of a shock or sudden change of acceleration is undesirable and that a definite maximum rate of deceleration, limited by governing, is preferable to a gradual but steady increase of the rate of deceleration up to the instant when the drum is brought to rest and the deceleration suddenly falls to zero. Analysis also shows that the most favorable building-up period under a steady increase of rate of deceleration is t (necessarily less than the total braking period) = $2\pi L/(c\lambda_1)$, the fundamental period of oscillation of the system, where c is the velocity of stress propagation in the rope and $\lambda_1 \tan \lambda_1 = mL/M$, and, further, this rate of deceleration attained, having been kept steady for a suitable period, should be gradually reduced to zero over a similar period of time to similar advantage. Numerical practical data are taken to elucidate and correspond closely with the analysis made. Author believes that his analysis is an improvement on that of J. Perry and D. Smith [Proc. Instn. mech. Engrs 123, p. 537, 1932]. Tensions at the bottom of the rope, which are considered more important, are also obtained in cases of dropping a load into a hanging skip, skip loading with varying load, and pickup from rest.

AMR #2577 (September 1952)

261. Pomp, A., and Duckwitz, C.A., "Fatigue Tests on Steel Wires Under Alternating Load," Mitteilungen aus dem Kaiser-Wilhelm-Institut fur Eisenforschaug, 13, 1931, pp. 79-91.

Patented and drawn wire of carbon content of .43 to .83 percent reduced by drawing from 44 to 90%. Subjected to endurance tests under varying tension. Greatest endurance found in wires of low carbon content.

262. Pomp, A. and Hempel, M., "Fatigue Strength Diagrams of Notched and Cold Worked Steels and of 1-in. and 1-1/8 in. Screws for Various Tensile Mean Stresses", Mitteilungen aus dem Kaiser - Wilhelm - Institut fur Eisenforschung, 1936, vol. 18, No. 14, pp. 205-215.

Determined limiting-stress curves of fatigue-strength diagrams. For carbon steels, limiting stress curves for smooth undeformed and for 10% cold worked steels were parallel. With zero mean stress the notch effect greater in the heat treated steel than in untreated carvon steel. Clear dependence of the mean stress on the notched-bar fatigue strength is shown. This could be important when analyzing cable fatigue depending on the magnitude of the effect of the mean stress.

263. Pomp, A. and Hempel, M., "Fatigue Testing of Steel Wires under Varying Tensile Stress. I. Influence of the Method of Manufacturing the Wire on the Strength under Fluctuating Stress," Mitteilungen aus dem Kaiser-Wilhel-Institute fur Eisenforschung, 1937, Vol. 19, No. 17, pp. 237-246.

Two steel wires of the same composition, one in the drawn, patented condition, the other in the tempered state, were subjected to fatigue stressing under varying tensile loads in air and under the water spray. The composition of the steel, the construction and mode of operation of the testing machine, and the method of calibrating it are described, together with the conditions observed during the tests and the interpretation of the results. In tests on the wire in the as-delivered condition no effects due to manufacturing method could be determined; in addition, the gradients of the varying stresses used confirmed that the alternating stress was independent of the mean stress. The decrease in strength under fluctuating tensile stress with simultaneous corrosion was found to be approximately 45.5 per cent, for both types of wire When the wires were deformed by bending prior to testing, the strength under fluctuating stress decreased and the corrosion-fatigue strength of wires so treated was equal to about a third of the strength under fluctuating stress of wires similarly treated and tested in air. Predeformation of the wires in torsion exerted a more unfavourable effect on the fatigue strength of the tempered wire than on that of the drawn, patented wire. The extent of the additional deformation by torsional stress appeared also to exert an effect on the strength under fluctuating stress.

264. Pomp. A. and Hempel M., "Fatigue Testing of Steel Wires under Varying Tensile Stress, II. - Influence of the Drawing Conditions on the Fatigue Strength of Steel Wire in Tension under Stresses Fluctuating Between a Minimum and a Maximum Value," Metteilungen aus dem Kaiser-Wlhelm-Institut fur Eisenforschung, 1938, Vol. 20, No. 1, pp. 1-14.

The fatigue strength under tensile stresses fluctuating between maximum and minimum values was determined on 36 steel wires of the same chemical composition produced from rods of the same initial diameter with diferent degrees of reduction per pass, different drawing media, and a die angle of 15°. To determine the fatigue strength the Wohler curves were plotted diagrammatically, and it was found that with increasing cold-working the angle of bend in the Wohler curves before reaching the limit of 2 X 10° fluctuations remained practically constant for series drawn under any given set of conditons. In the case of the steel wires investigated, no definite relationship between the fatigue strength and the reduction per pass or the lubricant was observed for equal total reductions, nor did it prove possible to correlate the fatigue strengths obtained with bend- or torsion-test data. Nevertheless the fatigue values obtained ran a closely parallel course to the tensile-strength values.

265. Pomp, A. and Ruppik, H., "Influence of the Rate of Running Through in the Lead Patenting of Steel Wire on the Strength Properties of the Drawn Wire," Mitteilungen aus dem Kaiser-Wilhelm-Institut fur Eisenforschung, 1935, Vol. 17, No. 23, pp. 259-274; Stahl and Eisen, 1936, Vol. 56, Aug 6, pp. 899-903.

A 0.66 per cent. carbon steel wire was patented with various quenching and lead-bath temperatures and with three different speeds of passage through the bath. The time during which the wire remained at a temperature above A_3 (determined by the speed and furnace temperature and length) was measured by a thermocouple welded to the wire. The results show that a change in the rate of passage has a marked influence on the properties of the wire in their relation to the quenching and bath temperatures. The most suitable conditions for patenting and draughts in drawing for the attainment of the best properties in the wire, particularly the flexibility and torsion number, are indicated. The authors have also sought for a meaning of a maximum in the torsion number observed after medium draughts in drawing the wire.

266. Powell, R.B., All American Engineering Co, Wilmington, Del, <u>A Study of the Causes of Wire Rope Failure in Oceanographic Service</u>, Sept., 1967 (Rept. n.N-576), (Contract N62306-67-c-0287) AD-658871

267. Protection of Cables,"Neoprene protects cables," Under Sea Technology Preprint P 795.

Flexible cables are used to connect the power generators on the tender ship to the drilling platform which together make up the Arabdrill 2 now operating in the Arabian Gulf, More than 15 km (9 miles) of cables make up the link.

To protect the cables against the conditions-the continual movement of the ship, the temperature, and occasional immersion in salt water - the cables are jacketed in Du Pont Neoprene. In the two years the system has been operating, there has been no cable failure in Arabdrill 2 or in the smaller installation of Arbdrill 1.

268. Prus, A.A.,"A new machine for torsion tests on wire (in Russian)," Zavod. Lab 21, 4, p. 489, 1955; Rev. no. 1864, Ref. Zh. Mekh. 1956.

A description of the layout and construction of a machine with a pendulum for measuring the torsional moment and a separate meter for the angle of twist of the sample. This latter is determined as the difference of the angles of rotation of two gear wheels attached on the wire sample under test; which excludes distortion of the readings by the effect of the machine grips. A registering device is incorporated.

Machines have been built on this principle up to 40 - 400 kg/cm.

AMR #2551 (1957)

269. Pungel, W., "The Effect of After Treatment on the Properties of Steel Wire," Stahl and Eisen, 1942, Vol. 62, Oct. 8, pp. 853-858; Oct 15, pp. 876-879; Iron and Steel Institute, 1945, Translation Series No. 253 (English Translation of the above).

The author review experience gained by the Vereinigte Stahlwerke A -G., concerning the effects of heat-treatment and deformation on the properties of steel wire. Tempering at between 250° and 350°C. increased the elastic limit and tensile strength of drawn steel wire, whilst tempering at higher temperatures had the opposite effect; the reduction in tensile strength was greater the greater the reduction of area on drawing and the longer tempering time. The reduction of area in the tensile test decreased with decreasing temperature below 250° C.; at above 250°C, it increased with increasing tempering temperature for small reductions on drawing, but for large reductions it decreased; for medium reductions on drawing the reduction of area was not affected by the tempering temperature.

270. Rahlfs, P., and Masing, G., "Investigation of the Bauschinger effect in torsion of wires (in German)," Z. Metallk. 42, 12, 454-459, Dec. 1950.

Authors report torsion tests on wires (0.8-1.0 mm) of carbonyl iron, soft iron, hard copper, brass, tin-brones, aluminum, aluminum-manganses alloy, aluminum-magesium alloy. Tests consisted in initial twisting well into the plastic range, followed by reversed twisting through the elastic and into the plastic range. Divergencies between the load-deformation relation during reversal and that predicted from the initial loading relation were partly due to strain-hardening, partly to the Baushinger effect. Iron, bras, and tin-bronze showed a relatively strong Bauschinger effect, while copper, aluminum and aluminum alloys showed a relatively weak effect.

AMR #437 (1952)

271. Rakoff, Frank B., "Effects of Certain Ship Motions on Cable Tensions in Systems for Handling Submerged Bodies," Underwater Sound Lab., Report No. 558, August 1962.

Conditions for zero towline tension of any fishship combination are studied. The report shows that the towline tension is zero when the downward magnitude of the acceleration of the towpoint of the ship is greater than the downward acceleration of the fish. This phenomenon can occur becauae the only forces available to accelerate the fish are its water weight and its vertical drag. The report gives equations describing the path of the towed body and the consequence of the ultimate recapture of the body.

272. Reemsnyder, H. S., "Correlation of fatigue limit with true stress-true strain behavior," Materials Research & Standards 7, 9, 390-391 (Sept. 1967).

It has been widely accepted that the ratio of fatigue limit to tensile strength (for a given test stress ratio) is relatively constant. Recently, however, a correlation was shown between the rotating bending fatigue limit and the true stress-true strain parameters of steels. This paper extends the correlation to axial load fatigue tests of low and medium strength steels. Error analysis shows that fatigue limits may be estimated with acceptable precision for strain hardening exponents greater than 0.1

AMR #2609 (1968)

273. Rinhart, Fred M., "Corrosion of Materials in Hydrospace," U.S. Navy Fourth Symposium on Military Oceanography, Proceeding, 1, 265-288 (1967).

274. Reynolds, E.S., "Proper Lubrication of Wire Rope Pays," Pit and Quarry, 56, 112-115 (Sept. 1963).

275. Rhodes, R. and Turner, F.H., "Design of End-Blocks for Post-Tensioned Cables," Concrete 1, 12, 431-434 (Dec. 1967).

276. Richardson, William S., "Buoy Mooring Cables, Past, Present and Future" Transactions, 2nd International Buoy Technology Symposium, 1967, Washington, D.C.

The author states that the most serious problem in buoy technology is the design of mooring cables. No single technical development is as important to the future of oceanography as the ability to moor buoys in the open ocean for extended periods of time. The different modes of failure of cables are analyzed.

277. Rigo, Jane H., "Corrosion Resistance of Stranded Steel Wire in Sea Water," Materials Protection, 5 (4), 54-58 (April 1966).

278. Ringleb, F.O., "Motion and Stress of an Elastic Cable Due to Impact," ASME Summer Conf. Berkeley, Caoif., June 1957. Pap. 57-APM-10, 9 pp.

Relation between impact stress and impact velocity in general case of an oblique impact at a cable has been determined. Relation includes as special cases Saint-Venant's formula for the longitudinal, and author's formula, given in 1948, for the perpendicular impact stress. Using a slight approximation, general formula has been represented by a graph for which impact stress can be determined for a given impact velocity, a given impact angle, and any practical values of the cable material constants and its initial stress. It has been verified that the impact energy and the kinetic and strain energy of the cable are correctly balanced because of the oblique impact relation. Measured impact stresses are compared with theory in case of perpendicular impact for three different cable diameters.

AMR #397 (1958)

279. Riparbelli, C., "On the Relation Among Stress, Strain and Strain Rate in Copper Wires Submitted to Longitudinal Impact," Proc. Soc. exp. Stress Anal. 14, 1, 55-70, 1956.

Series of exploratory tensile impact tests on copper were made to investigate mechanism of plastic deformation. Results confirmed earlier observation that velocity of elastic wave is constant and independent of any plastic flow. Rate of plastic flow was found to approximate linear function of "excess of stress", the difference between dynamic stress and static stress for same plastic strain.

AMR #2047 (1957)

280. Ritter, Owen, "Determination of a Reliable Wire Rope System for Application to the Deep Submergence Systems Program DSSP/Large Object Salvage System (LOSS)," Code 027, NSRDC, Oct. 196

Problem of reliability of lift system where bending fatigue is considered the most critical problem. States that fatigue under axial loading is neglibible Discusses work by Drucker and Tachan as the only theoretical method of estimating fatigue of wire rope. Noted lack of NASL or rope industry investigations into the validity of Drucker's analysis. Makes recommendations based on best practice for design of system. Recommendation of full-scale test of system.

281. Robertson, S.C., and Dunstant, R.A., "Bending of Wire Ropes in Flying Foxes," J. Instn. Engrs., Austral. 25, 3, 45-51, Mar 1953

In this study the cable is analyzed as a beam loaded with an axial tension force and concentrated lateral loads from the carrier wheel or wheels. This assumption leads to the usual hyperbolic solution.

The principal assumptions are that the sag of the cable is fairly small, generally not exceeding 1/10 of the span, although the results are roughly true for a sag of 1/5 of the span, and that the elastic limit is not exceeded.

Expressions for the bending moment and the equivalent tension due to bending moment are given for the case of a single wheel carrier on a flying fox, and also for the cases of double- and multiple-wheel carriers.

These expressions define, in normal conditions, upper limits to the bending moment and the equivalent tension. Values determined from them will not generally be exceeded in practice, nor will the actual moments and equivalent tensions be less, except possibly in the case of very flexible ropes passing over exceptionally large sheaves in single- or perhaps double-wheel carriers in a flying fox with a relatively large sag ratio.

The results may be extended to ropes passing over sheaves generally, provided that the angle turned through by the rope does not exceed 45° as an absolute maximum.

Some practial results are given, including rough figures to indicate the conditions when the elastic limit of the wires is exceeded.

AMR #747 (March 1954)

282. Roebling Wire Rope Co., "Roebling Wire Rope Handbook," Trenton, New Jersey, 1966.

283. Rosetti, U., "Fatigue Strength of Wire Ropes. Endurance Test Under Combined Bending and Tension," (in Italian), Ingegnere 27, 7, 769-771, July 1953.

Emphasis is placed on correct and exact determination of cable strength under dynamic test. A new fatigue-testing machine is described and the advantages and adaptability of the equipment used are discussed briefly. Experiments were conducted on several types of wire ropes. Comparative results c the behavior of every type under fatigue test are also presented.

AMR #246 (March 1954)

284. Rossnagel, W.E., "Handbook of Rigging," McGraw Hill Book, Co., New York, (1964).

285. Rowland, E.H., "Graphic Analysis of Guyed Masts," Structural Engineer, 46, 5, 147-152 (May 1968).

When a mast is displaced from the initial position by wind loading, changes in length of stay chords occur, causing changes in initial tensions in the stays. Author presents a graphical method for relating these changes to the initial tensions, and for determining a set of initial tensions which will assure the desired straight-line deflection of the mast. Results indicate that heavy stays with moderate initial tensions are preferable to light stays with high initial tension.

Method contains approximations but may be accurate enough for many applications, particularly in preliminary designs. No account is taken of wind loadings on stays themselves or of vibratory effects. Paper should be of interest to designers of tall radio and television towers and similar structures.

AMR #4984 (1969)

286. Sachs, G. and Sieglerschmidt, H., "Tensile and Bending Tests in Cable Wires," Metallwirtschaft. 8, Feb 8, 1929, pp 129-138.

287. Safety test for wire rope, "How Wire Rope Tester Promotes Safety, Increases Service Life," Metal Mining and Processing, July 1964.

Describes use of an electomagnetic device to inspect mine hoists and augment visual inspection.

288. Salceanu, C., and Aczel, C., "Theoretical Analysis of a New Viscoelastic Constant for Solids Drawn Into Wires," (in French), Comptes Rendus Hebdomadaires des Seances de l'Academie des Sciences, Series A, Sciences Mathematiques 264, 11, 524-526, (March 1967).

AMR #6920 (1969)

289. Savin, G.M., "Basic Dynamic Equations of a Mine Lifting Cable(load lifting)(in Russian)," Applied Mechanics, 1, 1, 5-22, 1955; Ref. Zh. Mekh. 1956, Rev. no. 3122.

In the selection of the relationships between the stresses and the longitudinal deformations of the cable, author bases himself on the oscillograms of free oscillations of the end load Q_o, obtained at various values of the initial amplitudes and length of the rope.

The basic equations of the dynamics of a cable are derived during lifting of the load

$$-\frac{q}{g}\left(\frac{d^2\xi}{dt^2}\right) - \frac{q}{g}\left(\frac{\partial^2 u}{\partial t^2}\right) = -\frac{\partial T}{\partial x} + q$$

$$\frac{Q}{g}\frac{d^2\xi}{dt^2} = Q - T(0,t) + R$$

where q is the weight of the linear length of the cable, ξ the variation in the length, u the absolute elongation of the cable of a length x, Q the weight of the load, T the stress in the cable and R the force of resistance to the movement of the load.

At the same time, the following boundary and initial conditions are considered

$$u(0,t) = 0, \quad \frac{d^2\xi}{dt^2} = \frac{dv_c}{dt} + \frac{dl}{dt}\left(\frac{d^2u}{\partial t\partial x}\right)_{x=l} + \left(\frac{d^2u}{\partial t^2}\right)_{x=l}$$

$$u(x,0) = m_1x + m_2x^2, \quad \left(\frac{\partial u}{\partial t}\right)_{t=0} = m_3x$$

at $$T = K\left(1 + i\frac{\delta}{2\pi}\right)\frac{\partial u}{\partial x}$$

where v_c is the velocity when moving the load, K the longitudinal rigidity m_1, m_2, m_3 are constants, δ the damping decrement.

In the case of a small lifting depth

$$u(x,t) = x\,\epsilon(t)$$

the problem is simplified and reduced to integration of the equation

$$\frac{Ql}{g}\frac{d^2\epsilon}{dt^2} + \frac{Qv_c}{g}\frac{d\epsilon}{dt} + K\left(1 + i\frac{\delta}{2\pi}\right)\epsilon(t) = \frac{Q}{g}\left(g - \frac{dv_c}{dt}\right)$$

in the boundary conditions

$$\epsilon(0) = m_1, \quad \frac{d\epsilon(0)}{dt} = m_3$$

Based on the method of moments and starting from the basic equations, a new system of integral differential equations is plotted, by using which it is possible to obtain approximate solutions of the problem in question. At the same time the particular cases are

indicated, for which the necessary solutions can be obtained fairly simply.

AMR #2791 (1957)

290. Savin, G.M., "Dynamic Forces in a Hoisting Rope on Raising a Load from an Immovable Foundation," (in Russian), Dopovidi Akad. Nauk Ukrain. RSR no. 2, 140-147, 1954; Ref. Zh. Mekh. 1956, Rev. no. 1652.

The rope is regarded as an elastically tough filament. The dynamic equation is derived for a mine hoisting rope, assuming the damping to be proportional to the velocity. Two stages of the process of hoisting the load are examined, the lifting of the load off a stationary foundation, and its further raising. The problem of determining the maximum stresses in the rope during hoisting is reduced to finding the first maximum in peak stress at the beginning of the second stage of hoisting, which is attained within a very short time interval-according to the author's calculations, the error should not exceed 1 %. The author is of the opinion that, in determining the dynamic forces inthe rope, the change in length of the latter and its incomplete elasticity may be ignored.

AMR #2470 (1957)

291. Savin, G.M. and Goroko, O.O., "Elastic Parameters of a Naturally Twisted Thread," (in Ukrainian), Dopovidi Akad. Nauk UkrSSR no. 8, 828-832, 1959; Ref. Zh. Mekh. no. 8, 1960, Rev. 10967.

The property of ropes to untwist under longitudinal stress and to become elongated as they untwist is considered. The concept of a naturally twisted thread with three elastic parameters, the longitudinal and torsional rigidity and also the coefficient of an-twisting(the elongation on untwisting through unit angle), is introduced. The problem is regarded as linear. Two examples of the calculation of ropes are given.

AMR #6471 (1962)

292. Savin, G.M., and Shevelo, V.M., "Dynamic Stresses in Lifting (load lifting) Cables for Shallow Mines (in Russian)," Reports of the Academy of Sciences of the Ukrainian SSR no. 2, 136-139, 1954; Ref. Zh. Mekh. 1956, Rev. no. 3121.

The longitudinal oscillations of the load Q are examined, which is suspended on a cable to a drum which rotates with a given linear velocity $v_c = v_c(t)$ about an immobile axis. The velocity $v_c(t)$ is given by a trapezoidal tachogram of lift; slipping of the cable over the drum is disregarded; the cable is assumed to be an elastic viscous thread.

Authors reduce the system of equations of motion for shallow mines to the equation

$$\frac{1}{g}\left(Q + \frac{\gamma \ell}{3}\right)\frac{d^2\phi}{dt^2} + \left[\frac{1}{g}\frac{d\ell}{dt}\left(Q + \frac{\gamma \ell}{2}\right) + \alpha\right]\frac{d\phi}{dt} + E_c\,\omega_{gn}\,\phi =$$

$$\frac{1}{g}\left(Q+\frac{ql}{2}\right)\left(g-\frac{dv_c}{dt}\right)$$

(in which q is the weight of a linear meter of cable, ω_{eh} the area of metal in the cross section of the cable) particular cases of which are already known: $\alpha \cdot l =$ const(Relei, "Theory of sound," Moscow, 1955, 1, 272); $\alpha = 0, q = 0$(N.P.Neronov, Notes of Leningrad Mining Institute, 23, 195-212, 1949); $\alpha = 0$(A. Yu. Ishlinskii, Reports of Academy of Sciences, USSR, 95, no.5, 939-941, 1954).

As a result of the qualitative investigation of the equation on the whole cycle of the lift, the criterion of damping of the stresses in the cable was established. For the purpose of illustration a graph of stresses f(l,t) was adduced, which was obtained as a result of the numerical integration of the equation for the case of initial values taken from one of the mines in operation.

AMR #3198 (1957)

293. Savin, G.N., "On Dynamic Forces in a Lifting Shaft Cable (in Russian)," Doklady Akad. Nauk SSSR (N.S.) 97, 991-994, 1954.

A lifting cable hangs over a revolving cylinder with fixed axis whose circular velocity is given. At the lower end of the cable a load of weight Q is attached resting on a fixed base. Let the force applied to the lower end of the cable before lifting the load be $T_0 \xi_0$ where $0 \leq \xi \leq 1$. As the cylinder begins to revolve, the lifting cable will first stretch out during an interval of time τ, the attached load remaining fixed on the support for $\xi \neq 1$. The load will start to move upward only after the force applied to the lower end of the lifting cable attains the value Q. The cable is considered as an elastic-viscous string, i.e., its stiffness at bending is neglected. Instead of the equations of motion for an element of the cable and the attached load, considered in a special case by Neronov (Akad Nauk SSSR Prikl. Mat. Mekh.(N.S.)1, 91-116, 1937), author introduces an integrodifferential equation (containing a parameter n) which is equivalent to the above mentioned equation in the sense that any solution of these equations satisfying the prescribed boundary conditions satisfies also this integrodifferential equation. The converse theorem, however is in general not true. By means of the integrodifferential equation author then constructs approximate solutions of the problem under consideration.

AMR #3291 (1955)

294. Savin, G.N., "The Dynamic Stresses in a Mine Winding Rope When Lifting a Load (in Russian)," Ukrain. Mat. Zh. 6, 2, 126-139, 1954; Rev. no. 412, Ref. Zh. Mekh. 1956.

The problem of determining the dynamic stresses in a winding rope which is wound on a drum rotating at a given velocity $v_c = f(t)$ is divi-

ded into two stages: (1) Removal of the end load Q from the stationary end. (2) Lifting of the load Q in accordance with the given trapezoidal tachogram.

The rope is assumed to be an elastic, viscous rope. Calculation of the internal resistance is based on Voight's hypothesis. The slipping of the rope over the drum during lifting is neglected. The problem is set of the solution of the well known equation of motion of the element of the rope.

$$\frac{\delta}{g}\frac{\partial^2 X}{\partial t^2} = -\frac{\partial T}{\partial x} + \delta$$

where, in accordance with what has been said above, the function of the stresses

$$T(x,t) = K\frac{\partial u}{\partial x} + \alpha\frac{\partial^2 u}{\partial x \partial t}$$

(α is the coefficient characterizing the damping of the dynamic stresses in the rope) with the following limiting and initial conditions

$$\left(\frac{\partial X}{\partial t}\right)_{x=l} = V_c, \quad u(0,t) = 0$$

$$u(x,0) = \zeta\frac{Q}{K}x - \frac{\delta x^2}{2K}, \quad \left(\frac{\partial u}{\partial t}\right)_{t=0} = 0$$

(ζ is the nondimensional value indicating the degree of unloading of the winding rope from the end load Q).

In view of the shortness of time of recording the value r of the end load Q from the stationary end. The problem of finding the function u(x,t) in the first stage of the lift is considerably simplified by neglect of the variation in the length of the rope, and by damping the dynamic stresses in it during the time τ. Solving the wave equation which is obtained from this, by D'Alembert's method, author finds the function $u^{(1)}(x,t)$ for the first stage, and the recording time τ , and knowing these, he determines the initial values of the required function for the second stage of the lift.

The graphs are given of the relationship of the value $k = c\tau/l$ to P/Q, ζ and a/g. In this, it is advisable for ease of calculation with the given values of a and ζ according to the given integer values $k = c\tau/l$ to determine the fractional values P/Q which correspond to them. The following tables are given: (1) the length l_0 of the plumb line of the rope for lifting at given values of $k = c\tau/l$. (2) the values ζ and $k = c\tau/l$ for the three values P/Q corresponding to lift with small (l_0= 105m), average(l_0= 410m), and large(l_0= 1020m) depths.

For describing the motion of the system load + lifting rope in the second stage of lifting, the author, using the conception of moments obtains the the integral-differential relationship, on the basis of which, making a first approximation of the solution in the form

$$u(x,t) = x\phi(t) + x^2\psi(t)$$

he reduces the problem of determining the dynamic stresses in the lifting rope at the second stage of lifting a load from great depths to integration of the system of twoordinary linear differential equations with variable coefficients.

AMR #1362 (1957)

295. Savin, G.N., and Georgievskaya, V.V., "Dynamic Forces in a Hoisting Cable When the Load is Taken off from an Immovable Foundation," (in Russian), Dop. Akad. Nauk, USSR no. 3, 205-211, 1954; Ref. Zh. Mekh. no. 12, 1956, Rev. 8458.

The article turns out to be a continuation of the work of G.N. Savin. In determining the maximum forces, the hoisting cable--not a fully elastic aggregate of the variable length-- is replaced by an ideal elastic thread of constant length, the top end of which travels upward with some (constant) increase in speed.

Two stages of the hoisting are examined: the taking off of the load from an immovable base and its movement upwards. In this way the problem merges with the integration of heterogeneous wave equation, with initial and boundary conditions, corresponding to the first and second stages of the hoisting. In the results of the examination of this problem, formulas are established for the determination of the maximum force in the cable when the load is removed from an immovable foundation:

NOT REPRODUCIBLE

for the hoist of the freely suspended load

where P and Q, respectively, are the weight of the working part of the cable and the weight of the end load.

AMR #2997 (1958)

296. Sawsa, H., "On the Elastic Winding of Circular Wire," Proc. 1st Japan Nat. Congr. Appl. Mech., 1951; Nat. Committee for Theor. Appl. Mech., May 1952, 129-133.

Obtaining the normal stress at a point on the cross section of a circular wire wound round a circular mandrel in amanner analagous to the simple bending of a bar, the total tension acting on the wire is expressed in terms of the radius of the mandrel, that of the wire, the distance of the neutral line in the cross section of the wire from the axis of the mandrel, and Young's modulus of the wire. Elastic stress components and principle stresses at a point are solved under the assumption of a large elastic limit, radius of the wire being considered small. These

principal stresses are employed in Nadai's yield condition to assess approximately the elastic-plastic boundary and the plastic region, corresponding to the yield strength of the material. Calculated numerical results for molybdenum wire are presented in the diagram.

[illegible] #55 (1955)

. [illegible]canlan, R. H. and Swart, R. L., "Bending Stiffness and Strain in Stranded Cables," IEEE Winter Power Meeting, New York, Jan 1968, Paper . [illegible]

[illegible]. [illegible]chneider, L., Mahan, T., and Burton, L. [illegible], "Tow Cable Snap Loads," ASME Paper 64-WA/UNT-8 presented at the Winter Annual Meeting, New York, N. Y., Nov. 29 - Dec 4, 1964.

[illegible] towing submerged bodies such as oceanographic instrument packages, the towcable may be subjected to severe loadings because of large-amplitude ship motions. These motions first cause the cable to become slack and subsequently subject it to impact stresses when the tension is recovered. A single-degree-of-freedom system is used to represent the system. The effect of body density and cable compliance in attenuating the dynamic stresses is discussed.

[illegible]. [illegible]chultink, L., and Spier H., and Wagt, A. v. d., " The Abrasion of Diamond Dies," Appl. Sci. Res. (A)5,1, 1-11, 1954.

The author attempts to explain the changes in shape of the bores of diamond wire drawing dies.

[illegible]. Schultz, A. B., and Ting, T. C. T., " Determination of the Stress-Strain Relations in a Wire Under Transverse Impact," Journal of Applied Mechanics, Trans of the ASME, Series E, 35, 2, 406-408 (June 1968).

[illegible]. Schultz, A. B., Tuschak, P.A., and Vicario, A. A., Jr., "Experimental Evaluation of Material Behavior in a Wire Under Transverse Impact," J. of Appl. Mech., Trans of the ASME Series E, 34, 2, 392-396 (June 1967).

Measurements were made of the displacement of a thin wire during transverse impact at velocities up to 5000 in. per sec. The results are compared with the predictions of the rate-independent theory of plastic wave propogation. It is concluded that an aluminum-magnesium alloy showed no rate dependence, while 0.9999 pure aluminum showed evidence of an increase of strength under impact loading; 0.9995 pure copper showed somewhat anomalous behavior, being apparently softer at moderate velocities of impact and harder at high velocities.

The experimental method, while having the advantage of minimizing the effects of lateral inertia, is relatively insensitive to changes in the material; it is shown by calculation that an increase in flow stress of 20% gives a change of less than 5% in the measured deformation. However the authors state that work in progress will result in a more

general technique for determining the stress-strain relations from the experimental data.

AMR #9305 (1967)

302. Schwier, F., "Contribution to the Problem of Mechanical Ageing in Hard - Drawn, Patented Steel Wires,"(in German), Stahl u. Eisen, 72, 2, 58-60, Jan 1952.

Author is primarily concerned with the mechanical property changes that come about through ageing and, in particular, through mechanical or strain aging. Specifically, the influence of temperature and time and especially the latter on mechanical aging is investigated through a multitude of tests with drawn wires of different carbon content (.4-.8 %) and size....see also AMR #917 (1953)

303. Segal, A. I., "Calculations for Guy Rope Systems(in Russian)," Trudi Mosk. tekhn. in-ta ryh. prom.-sti i Kh-va. no. 5, 103-117, 1953; Ref. Zn. Mekh. no. 1, Rev. 1151.

The problem of the stiff mast guyed with a large number of ropes is solved by the method of deformations, while taking into account the chain stresses due to the gravity pull of the ropes, which leads to the nonlinear relation of the tension of the r opes to the change of position. The transcendental equations obtained are solved by the approximation method; first, on the assumption that the rope is inextensible, and when considering its elastic deformations. Two numerical examples are given.

AMR #3951 (1958)

304. Sergeev, S.T., "Influence of the Mode of Connection Between Cable and Loading Weight Upon the Stresses in the Cable Bent Around a Pulley (in Russian),"Prikl. Mekh., 1, 6, 63-70, 1965.

The author considers the magnitude of supplementary forces occurring in an elevator cable due to the running on the pulley. This magnitude depends on the connection of the second end. Two such cases are considered: the motion along a guide of a cable having a load attached to its end (elevator cable) , and the case of cables which run from one pulley to another. Several particular cases are examined.

AMR #2805 (1966)

305. Sergeev, S.T., "Investigation of the Process of F[illegible] Curved Cable on a Pulley(in Russian)," Prikl Mekh, 1, 4, 7[illegible] 1965).

In accumulating cable [illegible], the process of [illegible] the curved cable introduces an additional stress to elements. [illegible] the results of the investigation which has been carried out, it is shown

that the value of the additional stress, and consequently, of the strain during the forming period of the cable, attains significant values and in individual cases the expansion stress is equal to the tensile stress produced by the load. For the strength calculation of the cable, it appears that these stresses should be taken into account.

AMR #7224 (1967)

306. Sevastano, F., "Selecting Wire Rope for Oceanographic Applications," Undersea Technology Reprint R 191, Compass Publications. Reprinted from Undersea Tech, Feb 1967.

Terminology for wire ropes is discussed. Discussion of flexibility in terms of the length of the lay. Abrasion protection is discussed. Also discussed are strength, corrosion resistance and economical choice of a cable. Suggests improvements for wire rope. Presents fatigue curves comparing jacketed and unjacketed cable (plastic jacket), with jacketed cable showing a definite improvement in fatigue life.

307. Shanley, F.R., "On the Strength of Fine Wires," Rand Corp. RM-2011 (ASTIA AD144 288), 19 pp., Sept 1957.

A theory for the exceptionally high tensile strength of very fine wires (or fibers) is developed on the basis that the "core" material slips at nominal stresses, while the "skin" material must develop a very high tensile stress in order to completely disrupt the atomic bonds. The resulting equation gives excellent correlation with test data. The physical significance of the theory is discussed, as applied to glass and metal fibers. Suggestions for further study and tests are included.

AMR #1124 (1960)

308. Shaslov, V. I., "On the Influence Exerted by Thermal Treatment and Friction on the Internal Dissipation of Energy in Carbon Steels (in Russian), Trudi Nauchno-Tekhn. Soveshchaniya po Izuch. Rasseyaniya Energii pri Kolebaniyakh Uprugikh Tel., Kiev, Akad. Nauk USSR, 174-192, 1958; Ref. Zh. Mekh., no. 2, 1960, Rev 2702.

Investigation on the changes in the internal dissipation of energy in carbon steels in relation to their heat treatment, regime and duration of work on the material under the action of cyclic loading and rest... .... see AMR #2107 (1962)

309. Shelton, S.M., and Swanger, W.H., "Fatigue Properties of Steel Wire," J. of Res. of the Nat. Bu. of Stds, 14, Jan 1935, pp 17-32.

Effect of surface condition (finish) on the fatigue properties. Effect of mean stress on limiting range of varying tensile stress determined for cold-drawn and galvanized, and heat treated and galvanized, steel suspension bridge wires, and on high carbon steel wire zinc electroplated. Concluded that effect was insignificant.

310. Sherwood, P. W., "How to Stretch the Life of Your Wire Rope," Rock Products, 69, 125, Jan. 1966.

311. Shield, R.T., "Plastic Flow in a Converging Conical Channel," J. Mech. Phys Solids, 3, pp 246-258 (1955).

312. Shinoda, G., Kajiwara, N., and Kawabe, H., "Dynamical Behavior of a Nylon Climbing Rope," Technol. Rep. Osaka Univ., 6, 43-52, Mar. 1956.

Dynamic behavior of a nylon climbing rope was studied. Nylon 11mm withstands up to H/L equal to 0.3 for a falling weight of 55kg, H being the height of the falling weight and L the length of the rope. These correspond to impulsive load of nearly 600 kg for both ropes. Calorimetric study was made during shock test and compared to the result of the measurement of temperature rise during static tension test. Nearly 600 kg, which coincided with above figure , was obtained. Nylon rope shows good characteristics for shock loading, but they break easily by lateral file action of a sharp rock edge. This is a result of the low melting point and fusing of the element at the fracture is always observed.

AMR #1037 (1958)

313. Siebel, E., "The Present State of Knowledge About the Mechanical Phenomena of Wire Drawing," Stahl Eisen, May 22, 1947, vol 66/67, pp 171-180.

This article is an excellent review of recent developments in our understanding of wire drawing. While the author has given an analysis in which some rather broad simplifying assumptions are made, the results he obtains are fundamentally sound and consistent with experiment. His concluding charts are very interesting and may have considerable use in the actual laying out of the wire-joint sequence. A translation of this article into English would be of great value to American engineers.

AMR #68 (1949)

314. Siev, A., "Prestressed Suspended Roofs Bounded by Main Cables(in English),"Publications of the International Association for Bridge and Structural Engineering, no. 2[illegible], 171-186 (1967).

This is an analytical and experimental study of a simple model of a suspended roof bounded by main cables. The model consists of 28 bars and approximates a hybar surface bounded by parabolic shape in plan. It is well known that a system of this shape is unstable. In the case of prestress, however, a certain degree of stabilization is provided; the lighter the prestress the stabler the system. In the experimental approach, loads were applied to all joints in 200 g increments from 0 to 2000 g. The analytical approach is based on the [illegible] theory, in spite of the larger number of equations [illegible] theory. The reasoning was the

simple presentation in a matrix form. Consequently, a program was prepared for the Philco 2000 computer. Good agreement was found between theory and experiment.

AMR #365 (1970)

315. Sines, G., "The Prediction of Fatigue Fracture Under Combined Stresses at Stress Concentrations," Bull. JSME, 4, 15, 443-453, Aug 1961.

316. Single cables, "Single Cables Subjected to Loads," Civil Engineering Transactions, Institution of Engineers, Australia, vol CE7, no. 2, October, 1965.

317. Sirotskii, V. F., Grigorev, N. I., and Artemev, P. I., "The Angles of Declination of the Load Lifting Cables of Gantry Cranes in Operational Conditions(in Russian), Tekhn. Transport no. 7, 19-21, 1959; Ref. Zh Mekh. no. 10, 1960, Rev. 12754.

Results are given of full-scale measurements of the angles of declination and the vibration frequencies of load lifting cables of turntable cranes in actual working conditions. Limits are obtained for the maximum angles of oscillations of the loads based on the analysis of oscillograms of 460 cycs of the work done by three types of cranes. It was established that the lack of uniformity of the data for the cycles can be attributed to the cranesmen adopting measures which reduced the swinging of the load. Graphs are shown to indicate the repeatability of the largest angles of declination of the load lifting cables expressed in percentages of the whole number of cycles investigated, and also graphs showing repeatability of the oscillation frequencies obtained. Formulas are given for the maximum angles of declination according to which it is essential to carry out the calculations for the strength of the cranes and of their mechanis ms; also formulas for those angles of declination frequently occuring in operational conditions, formulas for the calculation of the fatigue strength and power of the electric motors.

AMR #6983 (1962)

318. [illegible]iter, R. [illegible], Stange, W. F., and Komenda, R. A., "The Effect of Galloping and Static Stresses on Conductor Fatigue," Technical Session on Conductor Vibration and Galloping, Summer Power Meeting, IEEE, 1968.

319. Skillman, E., "Some Tests of Steel Wire Rope on Sheaves," T. P. vol 17, no. 229, U. S. Bureau of Standards, March 2, 1923, pp 227-243.

320. Sleeman, W. C., Jr., "Low-Speed Investigation of Cable Tension and Aerodynamic Characteristics of a Parawing and Spacecraft Combination,"

NASA TN D-1937, 59 pp., July 1963.

321. Smollinger, C. W., and Siter, R. B., "Influence of Compressive Forces on the Fatigue Performance of Bethalume Strand Wire," CP 65-237, presented at the 1965 IEEE Winter Power Meeting, New York.

322. Smislova, A., Loewer, A. C., and Eney, W. J., "Using SR-4 Gages to Measure Strains in Wire Strand," Product Eng, 24, p 214, April 1953.

Description of a technique for the measurement of stresses in the individual wires of a small steel strand.

323. Socketing, "Correct Socketing Prevents Premature Rope Failure," Engineering and Mining Journal, 168, 126, Nov 1967.

324. Sokolov, Yu. ., "Approximate Solution of the Basic Equation for the Dynamics of Hoisting Cable (in Russian)," Dop. Akad. Nauk URSR no.1, 21-25, 195- Ref. Zh. Mekh. no. 1, 1957, Rev. 999.

It is assumed that the lifting of the load off an immovable foundation is accomplished in accordance with a trapezoidal tachogram. An approximate solution is obtained with the help of averaging th e inertia terms of the equation. It is shown that for the phase of lifting the load off the immovable foundation the problem merges into the integration of a single linear equation. Approximate formulas are given for the determination of the duration of this phase. The examination of the remaining phases of the movement is merged with the solution of the system of two ordinary differential equations. To ascertain the dynamic pull in the lower end of the cable, an approximate linear differential equation of the fourth order is used.

AMR #3487 (1958) Translation by Ministry of Supply, England

325. Sc[illegible] "Determination of Dynamic Forces in Mineshaft Hoisting [illegible] (in Russian)," Prikl. Mekh., 1, 1, 23-35, 1955; Ref. Zh. Mekh [illegible] 1956, Rev. 8556.

A method is adopted, put forward earlier by the author, of applying to the approximate solution one differential equation in particular derivatives, describing the longitudinal oscillations of a mineshaft hoisting cable, deduced by G.N. Savin. The problem allies itself to the integration of the system of two ordinary linear heterogeneous equations with rational coefficients. From this system an approximate linear differential equation of the fourth order is deduced to determine the dynamic force in the lower end of the cable. Two variants (transformations) appear, which are useful in the approximate solution. The question is discussed on the behavior of the calculations of the system of two equations deduced by the author in the case when the length of the cable $l(t)$ is tending

towards zero.

AMR #2452 (1958) Translation, courtesy of Ministry of Supply, England

326. Sproles, E. S., and Hoke, J. H., "Zinc or Aluminum Coating, Which Gives the Best Corrosion/Fatigue Resistance?," Wire and Wire Products, 43, 9, 150-152, October 1968.

327. Srawley, J. E., and Brown, W. F., Jr., "Fracture Toughness Testing Methods," ASTM Spec Tech Publication No. 381, p133.

328. Stange, W. F., "Methods of Measuring and Recording Bending Amplitude," 31 CP 65-160, Presented at the 1965 IEEE Winter Power Meeting, New York.

329. Stange, W. F., Ault, G. H., and Capadona, E. A., "Radiographic Testing of Cables and Hardware for Power, "Materials Evaluation, 27,1, 16-22, January 1969.

330. Starkey, W. L., and Cress, H.A., "An analysis of Critical Stress and Mode of Failure of Wire Rope," ASME Ann. Meet., New York, N. Y., Nov-Dec 1958. Paper 58-A-63, 5 pp.

Many wire rope manufacturers and machine designers are under the impression that the significant stress in a wire rope is the tensile stress or possibly the stress due to tension and bending. This paper proves by mathematical analysis that by far the greatest stress in a wire rope results from Hertz contact stresses at points of contact of wire-on-wire, and asserts that the usual mode of failure of a wire rope is fretting fatigue initiated at such points of contact. Design relationships based on these concepts should be of great value to designers who use wire rope.

From author's summary

AMR #2354 (1959)

331. Steidel, R. F., "Factors Affecting Vibratory Stresses in Cables Near the Point of Support," Trans AIEE, Part IIIB, vol. 78, pp. 1207-1213, 1959.

332. Steidel, R. F., "Strains Induced in Transmission- Line Cables by Aeolian Vibration, Proc. Soc. Exp. Stress. Anal. 16, 2, 109-118, 1959.

333. Stimson, P. B., "Deep Sea Mooring Cables," Transactions, 2nd International Buoy Tech. Symposium, Washington, D. C., 1967.

334. Sun, T. C., Achenbach, J. D., and Herrmann, G., "Effective Stiffness Theory for Laminated Media," T. R. No. 67-4, Northwestern University, July 1967.

A method is proposed to derive displacement equations of motion for a laminated medium. The method is applied to study the propogation of free harmonic waves in an unbounded medium.

335. Sunderhauf, H., "The Use of Aluminum in Cable Technology," Aluminum, 45, No. 111-114, Feb 196?.

A survey of the historical development of the use of Al in cable technology

336. Swift, H. W., "The Elasticity of Wires and Cables," Engineering, 12, April 30, 1926, pp. 547-548; May 28, pp. 615-617.

Various methods of testing for the elasticity of wires and the comparative accuracy of certain of them is discussed.

337. Swift, H. W., "The Mechanism of a Simple Drawing Operation," Engineering, 178, 4627, pp. 431-435, Oct 1954.

Describes the drawing of sheets

338. Taira, S., and Koterazawa, R., "Investigation on Dynamic Creep and Rupture of a Low Carbon Steel," Bull. JSME 4, 14, 238-246, May 1961.

339. Taira, S., and Murakami, Y., "Residual Stresses Produced by Plastic Tension in Notched Plate Specimens and Fatigue Strength," Bull. JSME 4, 15, 453-460, Aug 1961.

340. Telephone, "New Techniques Used in Undersea Installation to Guard Cables," December 30, 1967.

341. Testing, "The Testing of Cables, Wires, Straps, etc.," Tsentralnyi Aerogidrodinamicheskii Institut Trudy, USSR, Translation, No. 33, Chapter 9 (1928). Available: DDC as AD 669 162.

342. Testing, wire rope, "Wire Rope Testing," Lab Project 930-44, Ltr Rpt. 932: MLF: cf, U.S. Naval Applied Science Lab, Brooklyn, March 1968.

343. Texas Instruments, Inc., "Evaluate, Test and Manufacture an Improved Wire Rope and Cable," (Sixth Qtly Progress Rpt), Prepared under Buships

Contract No. bs-92232, Dec 31, 1966.

344. Thompson, F. C., Carroll, J. B., and Bevitt, E., "The Drawing of Steel Wire at Elevated and Sub-normal Temperature," J. Iron Steel Inst., 173, part 1, 36-51, Jan. 1953.

Discussed among other results the effect on mechanical properties of wire due to drawing at extreme temperatures

345. Thompson, W. H. (Lord Kelvin), "On the Forces Concerned in the Laying and Lift of Deep Sea Cables," Math. and Phys. Proceedings, Vol. 2, Cambridge University Press, England, 1889, pp. 153-167.

346. Thorpe, T. and Farrell, K. P., "Permanent Moorings," Trans. Inst. Naval Architects., Vol. 90, pp. 111-153, 1948.

347. Th. Whyss, "Effect of Secondary Bending and Internal Compression on the Lifetime of Stranded Wire Ropes with Hemp Cores (in German)," Bauztg. 67: 193-198 (Apr 2); 212-215 (Apr 9); 225-228 (Apr 16) 194?.

The paper forms part of a more extensive publication, which will be issued as report no. 166 of the Swiss Federal Materials Testing Inst. (E.M.P.A). It consists of three sections, the first of which deals with the calculation of secondary bending stresses in stranded wire ropes. It is shown that these stresses may be of considerable magnitude, which yields an explanation of the results of fatigue tests made by Woernle and Herbst.

The second section gives an analysis of the loads and stresses between the component parts of the rope and pulley, caused by axial tension of and by transverse forces on the rope. In addition, the results of transverse loading tests in the plastic region and of bending and torsion fatigue tests with single wires are communicated.

In the third section the formulas are applied for ropes, the dimensions of which have been determined using a design criterion given by Drucker and Tachau.* The stresses determined in this way are in good agreement with an empirical formula, based on tests carried out at E.M.P.A. In a final section, the important conclusions of this investigation have been summarized.

see article # 90 of the present survey

AMR #448 (1950)

348. Torque balanced wire rope, "Torque Balanced Wire Rope," Trans of the 1964 Buoy Technology Symposium, Marine Technology Society, 24, 25 March 1964, Washington, D. C.

349. Tsuboi, Y., and Kawaguchi, M., "Design Problems of a Suspension Roof Structure - Tokyo Olympic Swimming Pools (in English)," Report of the Institute of Industrial Science, Tokyo University, 15, 2, 111-164 (Nov 1965).

The authors have described the methods of analysis and design of the swimming pool roof built in Tokyo in 1964. It consists of suspended cable networks, a system which has become increasingly popular in the last 20 years and has a considerable importance in view of its economy and ease of construction.

The authors have described the experimental work carried on 1/100th and 1/30th scales of the structure, which is instructive.

The cable network has double curvature. The bracing cables are completely flexible, but the carrying cables have a certain degree of bending stiffness. It has been pointed out that the geometry of the structure can be altered as desired by changing the distribution of bending stiffness, whereas this would not be possible with completely flexible cables.

The computed and experimentally obtained values for deflection and strains have not been compared. It would have been very useful if that had been done.

AMR #2521 (1967)

350. Tuman, C., "High Velocity Engagement of Arresting Wires," U.S. Naval Air Missile Test Center, Point Magu, California, 1954.

351. Tung, D. H. H., and Kudder, R. J., "Analysis of Cables as Equivalent Two-force Members," Engineering Journal N Y, 5, 1, 12-19, Jan 1968.

This paper presents a simplified analysis by treating cables as equivalent two-force members. The nonlinear behavior of cables is accounted for by introducing the concept of equivalent modulus of elasticity and equivalent strains. The stresses caused by a change in temperature, superimposed loads, or displacement of supports can be solved readily.

From author's summary

AMR #5908 (1969)

352. [illegible], K., "On the Tension of Towing Hawsers of Ships and Also of Chains Cables of Mooring Buoys," Mem. Fac. Engng., Kyushu Univ, 22, 2, 95-117, Mar 1963.

Paper contains two parts. In the first one the author discusses the variation of the stress in a towing hawser of ships, due to the influence of waves and gusts. Many particular cases are analyzed. The major assumptions are that the cable is inextensible, the weight of the hawser per unit length is uniform and the water resistance on the hawser movement is neglected. The conclusion is that in order to avoid cutting the cable due to different shocks, it is necessary to choose a cable as long as possible and the unitary weight be as big as possible.

The second part of the paper is devoted to the mechanics of mooring buoys. The conclusions are similar to the previous: to avoid the rup-

ture of the chain due to wind and wave effects, the chain must be as long and as heavy as possible.

The reviewer* wishes to note that today with the electronic computer technique one can solve any movement of an extensible cable for any movement of its ends and for any forces which act on the cable. In these conditions, the distribution of the strain and stress can be known at every moment of time and therefore the amortization of the shocks by the extension of the cable can be realized, in order to prevent the rupture.

* N.E. Cristescu, Roumania ...see article 59 of the present survey

AMR #3172 (1964)

353 United States Steel Corp., "Wire Rope Handbook," Columbia-Geneva Steel Div., San Francisco, Calif, 1959.

354. Valter, A. A., "Determination of Losses Due to Stiffness of Cables Because of the Small Angles of Contact of the Pulley (in Russian)," Trudi Penzensk. Industr. In-ta no. 3, 24-28, 1957.

AMR #2426 (1959)

355. van der Lingen, T. W., "Dynamic Behavior of Rope-guided Conveyances with Reference to Scale Model Testing," So. African Mech. Engr., 11, 5, 163-185, Dec 1961.

Author considers the two-dimensional motion of a mine hoist conveyance supported by a hoisting cable and four guide ropes. The two degrees of freedom considered are horizontal translation and rotation in the plane of the conveyance. Rope elasticity and internal rope friction are excluded (justification in appendix). The equations of motion set up for the conveyance and ropes seem correct , but the boundary conditions, Eq(4), seem incomprehensible both as far as the coordinate system and also as far as signs are concerned. It is the experimental results which make the reviewer feel that they may be correct.

AMR #4570 (1962)

356. Vanderveldt, H. H., and Gaffney, P., Patent Application, Differential Diameter Extensometer, 1969.

357. Veiler, S. Ia., and Likhtman, V. I., "Laws Governing Lubrication When Metals are Worked Under Pressure," Soviet Phys.-Tech. Phys., 2, 5, 989-995, Feb 1958.(Translation of Zh. Tekh. Fiz., Akad. Nauk SSSR 27, 5, 1087-1094, May 1957 by Amer. Inst. Phys. Inc., New York, N. Y.)

AMR #4985 (1958)

358. Vinogradov, V. V., et al., "Deep Sea Mooring," Bull. Scrips Inst. Oceanography, 8, 3, 271-312, 1963.

359. Voinea, R. P., and Voinea, D. P., "Contribution to the Strength Calculation of Flexible Electrical Conductors (in Roumanian)," Acad. Repub. Pop. Romine, Rev Mecan. Appl. 3, 3, 1958.

AMR #4375 (1959)

360. Wagerknecht, W. E., "The Production of Steel Wire," Wire Prod., 2, Jan 1953, pp 4-8.

361. Wagerknecht, W. E., "The Properties of Steel Wire," Wire Prod., 2, Feb 1953.

Reports that in the production of steel wires for wire ropes, a pre-anneal at 700° C gives a slight improvement in all test values. A decarburizing anneal at 1000° c causes the tensile strength and fatigue limit to decrease and leads to a marked improvement in the torsion test results.

BISI Bib 13 b

362. Wainwright, H. A., "The Distortion of Metals by Cold Working," Proc. of the Inst. of Mechanical Engineers, 137, Nov-Dec 1937, pp. 311-322.

363. Waldron, L. J., and Peterson, M. H., "Cathodic Protection of a Deep Sea Moor (AUTEC-TOTO II)," U.S. Naval Research Laboratory, Washington, D. C., NRL Memorandum Report 1338, July 1962.

364. Walton, T. S., and Polachek, H., "Calculation of Nonlinear Transient Motion of Cables," David W. Taylor Mod. Basin Rep. 1279, 50 pp., July 1959.

In this paper the system of partial differential equations governing the nonlinear transient motion of a cable immersed in a fluid is solved by finite difference methods. This problem may be considered a generalization of the classical vibrating string problem in the following respects: (a) the motion is two-dimensional; (b) large displacements are permitted; (c) forces due to the weight of the cable, buoyancy, virtual inertia of the medium and damping or drag are included; and (d) the cable is assumed to be non-uniform.

The solution of the problem is of practical significance in the calculation of transient forces acting on mooring lines due to the bobbing up and down of ships during the period preceding large scale explosion tests.

AMR #174 (1961) From authors summary

365. Watt, D. G., "Fatigue Tests on Zinc-coated Steel Wire," Wire and Wire Products, 1941, 16, May, pp. 280-285, 294, 295.

Vibration fatigue tests for strengths of 110 to 255 ksi. Concluded: (a) endurance limit increases as tensile strength while the endurance ratio decreases; (b) hot-dip galvanizing lowers endurance limit of patented wire by 15-29 %; (c) reduction by drawing increases the endurance limits of patented and zinc-coated wire; (d) electrolytic plating increased the endurance limit over hot-dipping.

BISI Bib 13

366. Weibull, W., " The Weibull Distribution Function for Fatigue Life," Mater. Res. and Stands., 2, 5, pp. 405-411, May 1962.

367. Weichbrodt, Bjorn, "Mechanical Signature Analysis, a New Tool for Product Assurance and Early Fault Detection," Report No. 68-C-197, General Electric R and D Center, Schenectady, New York, June 1968.

Sound and vibration signals have been useful for many years in judging the internal condition of machinery and structures. An automobile mechanic listens to an engine for internal defects. A machinist checks a grinding wheel for cracks by rapping it and listening for a clear or a dull tone. At General Electric's R & D Center, the interpretation of sound and vibration signals is being developed from an art into a scientific technique. This technique, Mechanical Signature Analysis, uses external measurement of sound and vibration signals to diagnose internal conditions or malfunctions and to detect incipient failure. Mechanical Signature Analysis has great potential as a unique tool for increasing the reliability and maintainability of a wide range of components, assemblies, and systems. (It seems possible, in principle, to use this approach in cable systems.)*

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* see article #200 of the present survey

368. Weisselberg, A., "Magnetic Crack Detection and Its Application in Rod Drawing Shops," Stahl und Eisen, 64, Dec 1944, pp. 791-797.

Description of magnetic powder testing of steel bars

369. Williams, A. E., "Steel Wire Ropes," New Zealand Eng., 7, Oct 1952, pp. 360-363.

Typical examples of wire rope construction. Importance of core is stressed. Metallurgy of rope wire, particularly the requirements for elastic modulus, yield point and fatigue limit are discussed.

370. **Williams, A. E.**, "Steel Wire Ropes; Some Factors Influencing Their Life," Iron and Coal Trades Review, 164, Jan 25, 1952, pp. 187-191.

Discussion of production of steel wire ropes and materials used in their manufacture. Factors affecting life are discussed, including: bending stresses, corrosion, and fatigue.

BISI Bib 13b

371. **Williams, A. E.**, "Ultrasonic Inspection of Wire," Wire Production, 2, July 1953, pp 4-7.

372. **Willis, J. M. N., Chisman, S. W., and Bullen, N. I.**, "Measurement and Suppression of Tension Waves in Arresting Gear Rope Systems," Aero. Res. Counc. Lond. Rep. Mem. 2981, 26 pp., 1957.

Experiments wre carried out in order to measure the effect of the tension waves which are introduced in an arresting gear rope system after engagement, and to try out means of suppressing these waves with a view to application to projected arresting gears suitable for entry speeds up to 120 and 150 knots.

Rope tensions were recorded for a series of tests covering a range of entry speeds up to 117 knots with a test vehicle weight of 5400 lb and up to 151 knots at a weight of 2,450 lb. It is shown that the amplitude of the tension waves becomes relatively greater with increase of entry speed and reaches very serious proportions at the maximum speeds obtained.

The use of resiliant rope anchorages has resulted in the suppression of the tension waves to a large extent, reductions in peak tensions of up to 30% under some conditions having been achieved.

From author's summary

AMR #398 (1958)

373. **Wills, W. H., and Findley, J. K.**, "Manufacture, Properties and Uses of 18-8 Chromium-Nickel Steel Wire," Trans of the Amer Soc for Steel Treating, 20, 1932, pp. 97-112, 112-114.

General wire drawing practice; 18-8 chromium nickel wire; physical properties of wire; corrosion tests

374. **Wilson, B. W.**, "Characteristics of Deep-sea Anchor Cables in Strong Ocean Currents," A & M College of Texas, Dept. Oceanography Meteorol. TR 204-3, 81 pp., Feb 1961.

375. **Wilson, B. W.**, "Elastic Characteristics of Moorings," Journal of the Waterways and Harbors Division, Proceedings of the American Society of Civil Engineers, 93, WW 4, 27-56 (Nov 1967).

By reviewing the pertinent literature, author collects many numerical data concerning the weight, ultimate strength, fatigue strength, and elastic properties of the mooring ropes, which usually consist of steel wires or fibers (nylon, Dacron, manila, etc.) woven together into strands and several strands into ropes. The behavior of mooring ropes under repeated loading is also treated. Formulas are given for calculating the dynamic effect exerted by waves on the moored ship and anchor cable. Several formulas are inserted referring to the geometry of harbor moorings and anchor line suspension.

This survey paper fills a long vacant niche in the literature of mooring operations.

AMR #4778 (1968)

376. Winding Rope Wire, "Winding Rope Wire, Patenting, and Continuous Drawing," Wire Ind., 19, Aug 1952, pp. 732-735.

377. Wire Rope Selection, "Wire Rope, Its Selection," the Rochester Corp., A-1-68, Culpepper, Virginia.

378. Wire Rope Selection, "Wire Rope, Its Selection, the Rochester Corp., A-2-68, Culpepper, Virginia.

379. Wire for Ropes, "Round Steel Wire for Ropes," British Std, BS 2763: 1968, 28 pp., June 1968.

This revised standard employing the metric system of units specifies the requirements for cold-drawn steel wire used in the manufacture of wire rope. Zinc plated and galvanized wires are considered with reference to the relevant standards. The manufacture, characteristics, inspection testing of the wires are dealt with a test for the adhesion of the zinc coating is described in one of the appendices. An additional section of the standard covers high duty round steel wire (including zinc plated or galvanized wire) for winding and haulage ropes. --ZDA

Source: Corrosion Abstracts, Vol. 8, No. 6, Nov. 1969, p. 413 line 1.

380. Wire for Ropes (Galvanized), "Galvanized Steel Wire Rope for Ships," British Standard, BS 365: 1968, 24 p (1968) May.

This revised standard specifies the requirements for galvanized round strand steel wire ropes for ships, including ropes for standing rigging, cargo lashings, moorings, towing and some types of cargo handling gear. The metric system of measurement is employed. The manufacture, characteristics and inspection of the ropes are covered along with testing procedures and delivery. The related standards are idicated. A list of terms and definitions (based on I.S.O. pro-

posals) is included in the appendices. --SDA

Source: Corrosion Asbstacts, Vol. 8, No. 6, p 413, Line 9, Nov. 1969

381. Wire Rope Handbook, "Wire Rope Handbook for Western Wire Rope User," Columbia- Geneve Steel Division of U.S. Steel, Copyright 1959, San Francisco, California.

382. Wistreich, J. ., "Profile Measurement of Wire Drawing Dies: Recent German Developments," Iron and Coal Trades Rev., Vol. 163, pp. 965-968 (1951).

383. Yamada, Y., "On the Application of the Theory of Plasticity to Hardness Test and Wire Drawing," Proc. 1st Japan nat. Congr. appl. Mech., 1951; Nat. Committee for Theor. appl. Mech., May 1952, 231-236.

Author considers slip-line fields for plane-strain indentation by a cylinder and plane-strain drawing through a die with cicular entry for the range of reductions where the slip-line field intersects the axis of symmetry in a single point. No velocity boundry conditions are considered.

AMR #133 (1955)

384. Yamanouchi, H., and Hyaski, I., "Drawing Force of Rod Through Die," Proc. 1st Japan nat. Congr. appl. Mech., 1951; Nat. Committee for Theor. Appl. Mech., May 1952, 237-240.

Paper gives an approximate stress solution for drawing through a rough conical die. The shearing stress in the axial direction is assumed to obey a power law normal to the axis.

Corrections for "change of direction of flow" at entry and exit are taken from Korber and Eichinger. Apart from this consideration, velocities are not considered.

AMR #134 (1955)

385. Yang, C.T., "On the Mechanics of Wire Drawing, ASME Trans. 83 B (J. Engng. Industry) 4, 523-530, Nov. 1961.

Single wire-resistance strain gage dynamometers are designed for measuring separating force and drawing force on a split drawing die, and the results of the estimation of (coefficient of friction) are presented. Importance of the effect of the land or paralled portion in the die is

emphasized. Using the estimated value of μ, drawing stresses are calculated and compared with experimental data. Drawing stresses derived from the author's equation are still low in comparison with the experimental results. This point is argued by Thomsen and Kobayashi in the discussion using Hill's slip line solutions, and reviewer is on the side of Thomsen and Kobayashi. A yield condition $\sigma_x - \sigma_r = \sigma_o$ would be more appropriate than equation (13) in the paper.

AMR #3297 (1962)

386. Yoshida, S., "On the Moments Applied to Wires During the Stranding Process," Proc. 2nd Japan nat. Congr. Appl. Mech., 1952; Nat. Committee for Theor. appl. Mech., May 1953, 109-112.

It is found experimentally that a stranded wire is twisted more easily than an unrestricted wire and that its torsional stress-strain characteristic is affected by the existence of stress resulting from the inevitable bending moments and torsional moments which are applied to it during the stranding process.

In this report, the stress produced by combined bending and twisting, and the moments applied to a wire during this process, are calculated theoretically.

AMR #2308 (August 1955)

387. Yoshida, S., "Studies on the Torsional Stress-Strain Characteristic of a Bent Wire," Proc. 1st Japan nat. Congr. appl. Mech., 1951; Nat. Committee for Theor. appl. Mech., May 1952, 123-127.

Considering the cross section of the bent circular wire to be partly elastic and partly plastic, author determines the torsional moments of such wire under the assumption that, in plastic region (i.e., after yielding has reached), (1) tensile stress σ of wire is constant and equal to that when it just yields; (2) torsional stress-strain plot beyond the yield point is linear, either parallel or makes an angle with the direction of strain axis; (3) shearing stress τ is given by $\sigma^2 + 4\tau^2 =$ const. Theoretical torsional stress-strain characteristic curves of copper, aluminum, and steel wires are plotted and compared with experimental ones and the author claims the results to be in good qualitative agreement.

AMR #56 (1955)

388. Zener, C., "Internal Friction of Wires," Nature, 140 Nov. 1937, p. 895.

389. Zinsser, R., "The Time-Yield of Steel Wires Stressed Within the Range of Fatigue Under Pulsating Tensile Stresses," (in German), Stahl. u. Eisen 3, 74, 145-151, Jan. 1954.

AMR #3572 (November 1954)

390. Gill, E.T. and Goodacre, R., "Some Aspects of the Fatigue Properties of Patented Steel Wires. II. Note on the Effect of Low-Temperature Heat Treatment," Journal of the Iron and Steel Institute, 1935, No. II, pp. 143-177.

Low-temperature tempering of cold-drawn wire is an essential process when the material is used in the form of a spring. The effect of this treatment on the fatigue properties has been examined for four steels of 0.37, 0.55, 0.79 and 0.86 per cent. carbon content respectively, drawn to varying reductions, from 25 to 90 per cent., and tempered in the range 150° C. The wires were free from decarburization but not polished. The following points were noted:

Generally there is an increase in the limiting fatigue strength, the optimum temperature being of the order of 200° C. (for one steel, 0.79 per cent. carbon, it was 150° C.).

With all the steels examined, there is a critical reduction, at which point under certain tempering conditions the limiting fatigue stress may fall considerably below that for the as-drawn condition. This critical reduction becomes progressively lower as the carbon content increases.

391. Lennox Jr., T.J., et. al., "Marine Corrosion Studies: Stress Corrosion Cracking, Deep Ocean Technology, Cathodic Protection, Corrosion Fatigue," Naval Research Laboratory, NRL Memorandum Report 1711, May 1966.

Studied cathodically protected type 304 stainless steel wire rope (7 X 9) and aluminized improved-plow steel rope (6 X & IWRC).

392. Plunkett, R., "Static Bending Stresses in Catenaries and Drill Strings," J. of Eng. for Industry, Vol. 89, Series B, February 1967.

The differential equation of bending of a stiff string is derived:

$$EI \frac{d^2\theta}{dZ^2} + h \cos\theta - Z \sin\theta = 0$$

where θ : slope angle

Axial elongation is derived. The paper shows that small stiffness causes and effect only in boundary regions near the end supports; the deviation from the catenary can be found as a rapidly converging series.

If one assumes that the string is in a flow current. the problem will

be interesting from the "cable" view point.

393. Poskitt, T.J., "The Application of Elastic Catenary Functions to the Analysis of Suspended Cable Structures," Struct. Engr. 41, 5, 167-170, May 1963.

An iterative procedure is given for determining the sag and insulator swing of high-tension cables. The paper consists mainly of a collection of interpolation formulas for the catenary functions, and a linearized stiffness matrix for small motions of the cable ends, all given without derivation because of their straightforward basis.

AMR #1 0 (1964)

394. Rust, T., et., al., "Evaluation of Titanium Alloy Cables for Air-Craft Use," Report No. NADC-AM-6709, Naval Air Development Center, 17 March 1967.

Description of results of tension and fatigue tests of titanium alloy cables to determine suitability as aircraft control cables and helicopter rescue cables. Results indicated that the poor fatigue of Ti cables make them unsuitable for these uses.

395. Schultz, A.B., "Large Dynamic Deformations Caused by a Force Traveling on an Extensible String," (in English), International Journal of Solids and Structures 4, 8, 799-809 (Aug. 1968).

An infinitely long, perfectly flexible string is subjected to two concentrated forces which travel along the string with constant speed in opposite directions from a common starting point. The ensuing motions and deformations of the string are described. The description takes into account large deformations, changes in string tension, and the transverse and longitudinal waves which propagate.

AMR #9413 (Dec. 1969)

396. Skop, R.A., "On the Shape of a Cable Towed in a Circular Path," Naval Research Laboratory, NRL Report 7048, April 24, 1970.

397. Vanderveldt, H., Laura, P.A.; and Gaffney II, P.G., "Mechanical Behavior of Stranded Wire Ropes," Report 69-4, Themis Program No. 893, Institute of Ocean Science and Engineering, Catholic University of America, July 1969.

398. Bibliography on Wire Rope, "Bibliography on Special Wire Rope Problems," Battelle Memorial Inst., Columbus Laboratories, Presented to the U.S. Navy on 30 July 1968.

399. Bibliography on Wire, "Bibliography on Wire," The Iron and Steel Inst. (Britain), Bibliographical Series 13, Prepared by the Library and Information Dept. of the Iron and Steel Inst., Harrison and Sons Ltd, London.

400. Bibliography on Wire, "Bibliography on Wire," The Iron and Steel Inst., (Britain), Bibliographical Series 13b, 1958, (Covers period 1946-1958).

401 Bibliography on Wire Rope, "Wire Rope Investigations at Naval Applied Science Laboratory," Bibliography, Lab Project 9300-44, Technical Memorandum 2, U.S. Naval Applied Science Laboratory,

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13. ABSTRACT

The purpose of ~~this~~ report is to determine the extent of literature available in regard to the "mechanical response of stranded cables". The survey has been organized into three categories, i.e., single wires, single strands and the composite wire rope. The various parameters, such as the mechanical response, the fatigue behavior, corrosion, corrosion protection, shock and impact and others have been considered under each of these major categories.

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